Monitoring of Special Status Plants

in the

Algodones Dunes, Imperial County, California

1977, 1998, 1999, 2000, 2001, and 2002

Bureau of Land Management
California State Office
2800 Cottage Way
Sacramento, CA 95825
October 2004

Cover photograph of sand food
(*Pholisma sonorae*)
by Debbie Sebesta

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Preface

The author of this report is John Willoughby, State Botanist, Bureau of Land Management (BLM), California State Office. This report is an update to a June 2001 report (Willoughby 2001). The June 2001 report documented the results of monitoring in 1977, 1998, 1999, and 2000. This report supplements the June 2001 report by providing monitoring results for 2001 and 2002.

Monitoring in 2001 and 2002 continued the design developed in 1998 by the author in collaboration with Debbie Sebesta, then with the BLM El Centro Field Office; Jim Dice, then with the California Department of Fish and Game; and Steve Hartman of the California Native Plant Society. Other individuals also provided input into the design (see Willoughby 2001 for the names of these people). An additional objective of the 2001 and 2002 monitoring was to conduct pilot sampling of the two species of greatest concern, *Astragalus magdalenae* var. *peirsonii* (Peirson's milk-vetch) and Algodones Dunes sunflower (*Helianthus niveus* ssp. *tephrodes*), to determine the feasibility and sample size necessary to estimate the actual population sizes of these two species in the Dunes (the design begun in 1998, and reported on here, is a modification of the approach originally used in 1977 by the consulting firm WESTEC; this study continued through 2002 and used an abundance class approach to monitoring which did not result in actual estimates of population size.) Because of the increased workload associated with counting individuals of these two species, three of the species monitored in 1977, 1998, 1999, and 2000 were dropped from the monitoring in 2001 and 2002: *Astragalus lentiginosus* var. *borreganus* (Borrego milk-vetch), *Croton wigginsii* (Wiggins' croton), and *Palafoxia arida* var. *borreganus* (giant Spanish-needle).

Monitoring was coordinated by Debbie Sebesta and Jim Dice in 1998, 1999, and 2000; by Debbie Sebesta in 2001; and by Chris Knauf in 2002. Steve Hartman and Allen Barnes of the California Native Plant Society assisted in garnering the support of the Society, which provided both paid personnel (funded through a contract with BLM) and volunteers to perform the monitoring. The following individuals actually conducted the monitoring: 1998: Debbie Sebesta, Jim Dice, Susan Hobbs, Fred Sproul, Tim Nosal, Heather Townsend, Kim Nicol, Steve Hartman, Diana Hickson, Glenn Black, Kelly Goocher, Debbie MacAller, Gary Wallace, Bob Bower, Florencio Bravo, Neil Hamada, and Jeff Hyrica; 1999: Debbie Sebesta, Ileene Anderson, Cindy Burrascano, Michelle Cloud-Hughes, Jim Dice, Susan Hobbs, Debbie MacAller, Tim Nosal, Jim Ricker, Todd Spear, Fred Sproul, Diane Steeck, Gary Wallace, Terry Weiner, Steve Geyman, and John Unger; 2000: Debbie Sebesta, Shannon Allen, Ileene Anderson, Jim Dice, Sheila Ferguson, Dave Guiness, Larry Hendrickson, Aaron Kania, Amy Kassameyer, Paul Kriz, Chris Knauf, Christian Layow, Rebecca Loomis, Kim Marsden, Brian Murdock, Tim Nosal, Susan Potts, Mike Powers, Jim Ricker, Fred Sproul, Terry Weiner, Mike Trost, and John Unger; 2001: Debbie Sebesta, Chris Knauf, Ileene Anderson, Bob Bower, Kevin Darby, Nicole Darby, Andrew Delage, Sheila Ferguson, Melanie Gokul-Prokurat, Kelly Green, Neil Hamada, Susan Hobbs, Esther Kim, Julie Kirker, Christian Layow, Ryelle Leverett, Todd Martin, Anne Mohnike, Bob Newsome, Daniel Patterson, Jeneine Schaffer, Tom Sharkey, Fred Sproul, Brian Stipek, Roxie Trost, Joelle Viau, Terry Weiner, John Willoughby, and Nelson Wright; 2002: Chris Knauf, Linda Belasco, Bob Bower, Gary Diridoni, Tyler Grant, Susan Hobbs, Larry

Hogue, John Johnson, Tsegaye Mengistu, Mike Meyer, Laura Moore, Jamie Neilans, Arnie Schoenberg, Shawn Stapleton, and Gavin Wright.

Fran Evanisko of the BLM California State Office provided valuable support in applying the ArcInfo Geographic Information System (ESRI 1998) to both the planning of the study and the analysis and presentation of the data collected. Ileene Anderson of CNPS and Shane Barrow, BLM California State Office, assisted with data entry for 1999 and 2000, respectively. Jamie Neilans and Tyler Grant assisted with data entry for 2002. Anne Knox, Shane Barrow, and Allison Sanger, all of the BLM California State Office, assisted in quality control of data entry.

Executive Summary

In 1998 the Bureau of Land Management (BLM) initiated a monitoring study of six rare plants of the Algodones Dunes, Imperial County, California. The study was designed to allow comparisons of plant abundance between 1998 and subsequent years to data collected in 1977 as part of an earlier study contracted by BLM. Monitoring for all six of the plants was conducted in spring and summer 1998, spring 1999, and spring 2000, and the results of this monitoring were reported in a separate report (Willoughby 2001). Monitoring of three of the six plants, Peirson's milk-vetch (*Astragalus magdalenae* var. *peirsonii*), listed as threatened by the U.S. Fish and Wildlife Service and as endangered by the State of California, Algodones Dunes sunflower (*Helianthus niveus* var. *tephrodes*), listed as endangered by the State of California, and sand food (*Pholisma sonorae*), a BLM sensitive species, was continued in 2001 and 2002. This report updates the 2001 report for these three species.

The major management issue in the Algodones Dunes concerns the effects of off-highway vehicle (OHV) use on the three special status plants. A large portion of the dunes north of State Highway 78 has been closed to OHV use since 1972, but the remainder of the dunes remained open to OHV use until November 2000, when interim closures of parts of these open areas were implemented as part of a lawsuit settlement. Because this study was initially designed to make inferences to the dunes as a whole, to the closed area, and to the open area, "open area" as used in this report continues to apply to the entire area that was open prior to the implementation of these interim closures. During data collection in 1998, 1999, and 2000, the open area was in fact entirely open to OHV use. In 2001 and 2002, however, part of the open area was closed to OHV use.

A total of 34 randomly selected transects through the dunes were surveyed by teams of two or more observers. Each transect consisted of contiguous cells 0.45 miles on a side. For each cell, observers placed each of the three species into one of five abundance classes, from 0 to not present to 4 for abundant (full descriptions of the abundance classes are given in the body of the report).

Healthy populations of all three species remain in the open area, though the above-ground expression of populations of Peirson's milk-vetch fluctuates dramatically with precipitation. There is no evidence of any OHV effect on either Peirson's milk-vetch or Algodones Dunes sunflower. An increase in sand food in the open area between 2001 and 2002 may result from a release in pressure from OHV use in the interim closures, but this is inconclusive and may be at least partially an artifact of sampling.

This is a monitoring program, not research, and there are limitations to using this information to assess the effects of OHV use on the three plants. These limitations were discussed in the 2001 report (Willoughby 2001).

Introduction

The Algodones Dunes (also called Imperial Sand Dunes) are an extensive system of sand dunes located in southeastern Imperial County, California. As shown in Map 1, they form an approximately 40-mile long belt trending in a northwest to southeast direction and range from 3 to 6 miles wide (WESTEC 1977). The dunes are almost completely public lands managed by the Bureau of Land Management. Most of the northern portion of the dunes (north of State Highway 78 which traverses the dunes in an approximate west to east direction above the latitudinal center of the dunes) is designated wilderness and closed to off-highway vehicle (OHV) use,[1] while the southern portion of the dunes are designated as open to OHV use (Map 2). On November 3, 2000, BLM implemented interim closures of parts of the open areas in the northern and southern portions of the dunes in response to a lawsuit filed by the Center for Biological Diversity, the Sierra Club, and the Public Employees for Environmental Responsibility regarding the Endangered Species Act (Map 7). As of the date of this report, the closures remain. They will continue until the record of decision for a new management plan for the dunes is signed by the BLM State Director; this is expected to occur in 2005.

The discussion in this report regarding parts of the dunes that are "open" or "closed" refers to the situation that existed prior to the interim closures. These terms accurately reflect the actual management occurring immediately prior to the monitoring in 1977, 1998, 1999, and 2000. For 2001 and 2002, however, the area called "open" in this report is a combination of areas actually open to OHVs and areas closed on an interim basis to OHVs.

Because of concerns over potential adverse impacts from off-highway vehicles (OHVs), the Bureau of Land Management (BLM) in 1998 initiated a program to monitor the following six plant species, five of which are BLM special status plants:

Astragalus lentiginosus var. *borreganus* (Borrego milk-vetch)
Astragalus magdalenae var. *peirsonii* (Peirson's milk-vetch)
Croton wigginsii (Wiggins' croton)
Helianthus niveus ssp. *tephrodes* (Algodones Dunes sunflower)
Palafoxia arida var. *gigantea* (giant Spanish-needle)
Pholisma sonorae (sand food)

Astragalus magdalenae var. *peirsonii* is federally listed as threatened pursuant to the Endangered Species Act and is listed as endangered by the State of California. *Helianthus niveus* ssp. *tephrodes* is listed as endangered and Wiggins' croton as rare by the State of California. *Palafoxia arida* var. *gigantea* and *Pholisma sonorae*, while not officially listed, are treated by California BLM as special status species by virtue of the fact they are considered to be rare and endangered by the California Native Plant Society (CNPS 2001). *Astragalus lentiginosus* var.

[1] Although the Wilderness designation was not enacted until 1994, essentially the same area now designated wilderness has been closed to OHVs since 1972 to protect the rare plants that occur there (an additional 60 acres were closed pursuant to the Wilderness designation).

borreganus is not federally or state listed, nor is it a BLM special status species (CNPS includes the plant on its watch list), but it was monitored anyway because it was surveyed in 1977.

The consulting firm WESTEC, under contract to BLM, conducted a study of these six plant species in 1977. BLM, using a similar study design, conducted monitoring of all six plant species in 1998, 1999, and 2000. In 2001 and 2002 monitoring was continued for *Astragalus magdalenae* var. *peirsonii*, *Helianthus niveus* ssp. *tephrodes*, and *Pholisma sonorae*. This document reports only on these three species. A previous report (Willoughby 2001) presented the results of monitoring of all six species for 1998, 1999, and 2000, and compared these results to the 1977 WESTEC data. An earlier report (Willoughby 2000) compared the 1998 results for all six species to the 1977 WESTEC data; that report contains more background information and detail on the study design. Both of these earlier reports can be downloaded from the California BLM website at the following address:

http://www.ca.blm.gov/elcentro/algdunesmonitorstudy.html

Methods

A grid was superimposed onto a map of the Algodones Dunes. The vertical and horizontal lines of the grid run (at least approximately) true north-south and west-east, respectively (Map 3). The cells formed by this grid are approximately 0.45 miles on a side. This grid was entered into the Geographical Information System (GIS), ArcInfo (ESRI 1998).

The 1977 study was conducted as follows. In the area open to off-highway vehicles (OHVs), WESTEC personnel, using a dune buggy, visited each of these cells by running transects west to east through the middle of each cell and rated each species into one of five density classes (counting zero as a class). It is unclear exactly how many cells WESTEC actually visited in the area closed to OHVs, but apparently many if not all of the cells in the closed area were ranked from a helicopter.

For all of the species except *Pholisma sonorae*, WESTEC used the following abundance (density) classes (the following descriptions come from WESTEC 1977; the abundance class 0, for no plants, is implied):

Abundance Class	Abundance Class Description
1	Presence of one or more plants occurring in low numbers, particularly adjacent to the observer, but not conspicuous farther away.
2	Presence of a moderate number of individuals of a species. Visible at a distance of up to 1/4 mile from the observer.
3	Presence of moderately high numbers of a species, forming a conspicuous element of the landscape.
4	Presence of very high numbers of a species, occurring throughout the quadrant (cell), representing some of the most dense populations encountered during the survey.

Because of the underground attachment of the parasitic plant, *Pholisma sonorae*, a different set of density classes was used for this species (WESTEC 1977; as in the table above, the abundance class 0 is implied):

Pholisma Abundance Class	Abundance Class Description
1	One to five inflorescences observed, most being dried inflorescences.
2	Six to 20 inflorescences observed, some still with flowers.
3	Over 20 inflorescences in the stand, but localized.
4	Over 30 inflorescences in stand, many in flowering state and well distributed in depression or vegetation habitat zone.

A random sample of 34 of the 66 west-east rows used in the WESTEC study was selected by BLM for monitoring in 1998, 1999, 2000, 2001, and 2002 (see Willoughby 2000 for details of the sampling design). West-east transects were run through the center of each of these 34 rows, sampling every cell in the row. Map 5 shows the positioning of these transects.

Monitoring teams were given the latitude for each transect (only one latitude value per transect was necessary since transects were run due west to east) and longitudes corresponding to the beginning and ending points of each cell along the transect. Each team used a hand-held Geographic Positioning System (GPS) unit, which they used to stay on the transect latitude and to determine the beginning and ending points for each cell. Data were recorded separately for each cell along the transect. As observers entered a cell they tallied every adult plant encountered and–if not too numerous to tally–every seedling plant encountered. For each cell, observers also gave separate abundance class rankings for adults and seedlings of each species. *Pholisma sonorae* was not ranked in the same way; rather than differentiating between adults and seedlings, observers separated counts and abundance class values for fresh and dried inflorescences of this species. The following abundance class rankings, which differed somewhat from those used by WESTEC, were used in the 1998-2002 monitoring studies (reasons for modifying the WESTEC ratings are given in Willoughby 2000).

All plants except *Pholisma sonorae*:

Abundance Class	Number of Plants
0	0
1	1-10
2	11-100
3	101-1000
4	1001-10,000
5	> 10,000

Pholisma sonorae:

Abundance Class	Abundance Class Description
0	No plants of the species were seen in the cell.
1	One to five inflorescences observed.
2	Six to 20 inflorescences observed.
3	Over 20 inflorescences in the stand, but localized.
4	Over 30 inflorescences in cell, and well distributed.

The closed area and the open area north of the closed area were sampled by teams of at least two observers who traversed each transect on foot. The open area south of Highway 78 was sampled by means of two persons riding a dune buggy, with one person driving and the other observing the target plant species (in 2002 four transects in the open area were read twice, once on foot and once using a dune buggy; only the values from the walked transects were used in data analysis). Teams consisted of botanists from BLM, the California Department of Fish and Game, the U.S. Fish and Wildlife Service, and the California Native Plant Society, which provided both paid personnel and volunteers. Volunteers from the American Sand Association assisted with the 2001 monitoring.

Precipitation data were collected from the Western Regional Climate Center (WRCC) for the following weather stations: Brawley 2 SW, El Centro 2 SSW, Gold Rock Ranch, Imperial, Yuma Citrus Station, Yuma Proving Ground, and Yuma WSP AP. The location of these stations in relation to the dunes is shown on Map 4. Gold Rock Ranch is the closest station to the dunes, situated less than 5 miles from the eastern side of the dunes about one third of the way up the dunes from their southern end. The next three closest stations are the Yuma WSO AP, which is about 10 miles southeast of the southern tip of the dunes, the Yuma Citrus Station, which is about 10 miles south-southeast of the southern tip of the dunes, and Brawley 2 SW, which is a little less than 20 miles west of the northern half of the dunes. Imperial and El Centro 2 SSW are about 25 miles and 35 miles, respectively, west of the dunes.

Precipitation data were collected for the growing seasons immediately preceding the six study periods: 1976-1977, 1997-1998, 1998-1999, 1999-2000, 2000-2001, and 2001-2002. Growing season was defined as the period between July and June. Although the months of May and June fall after much of the monitoring has taken place, essentially no precipitation fell during those months during the years of the study. Both Gold Rock Ranch and Yuma WSP AP stopped collecting weather data in 1996. Because of incomplete data, the Yuma Citrus Station was not used in the analysis of data for monitoring years 1999, 2001, and 2002.

Two remote area weather stations (RAWS) were installed in the dunes in fall 2000, one at Cahuilla Ranger Station in the northwest part of the dunes and one at Buttercup Campground in the southern part of the dunes (Map 6). These began collecting weather data on November 16, 2000.

Results and Analysis

The following tables show the dates the transects were surveyed in 1998, 1999, 2000, 2001, and 2002.

Transect monitoring dates in 1998:

Transect	Date	Transect	Date	Transect	Date	Transect	Date
1	17 April	10	15 April	19	28 June	28	13 Aug
2	17 April	11	10 April	20	29 June	29	11 Aug
3	17 April	12	9 April	21	29 Aug	30	1 Aug
4	16 April	13	9 April	22	29 Aug	31	1 Aug
5	16 April	14	9 April	23	28 Aug	32	29 July
6	15 April	15	21 April	24	28 Aug	33	28 July
7	15 April	16	21 April	25	15 Aug	34	28 July
8	15 April	17	21 April	26	15 Aug		
9	15 April	18	28 April	27	13 Aug		

Transect monitoring dates in 1999:

Transect	Date	Transect	Date	Transect	Date	Transect	Date
1	16 April	10	31 Mar	19	14 April	28	28 April
2	29 Mar	11	31 Mar	20	14 April	29	28 April
3	7 April	12	30 Mar	21	15 April	30	6 May
4	6 April	13	30 Mar	22	15 April	31	6 May
5	2 April	14	30 Mar	23	16 April	32	7 May
6	1 April	15	8 April	24	16 April	33	7 May
7	1 April	16	8 April	25	26 April	34	7 May
8	1 April	17	13 April	26	27 April		
9	31 Mar	18	13 April	27	27 April		

Transect monitoring dates in 2000:

Transect	Date	Transect	Date	Transect	Date	Transect	Date
1	7 April	10	4 April	19	10 April	28	14 April
2	7 April	11	4 April	20	10 April	29	14 April
3	6 April	12	5 April	21	11 April	30	19 April
4	5 April	13	5 April	22	11 April	31	19 April
5	3 April	14	6 April	23	12 April	32	19 April
6	3 April	15	4 April	24	12 April	33	20 April
7	3 April	16	4 April	25	20 April	34	20 April
8	4 April	17	5 April	26	13 April		
9	4 April	18	5 April	27	13 April		

Transect monitoring dates in 2001:

Transect	Date	Transect	Date	Transect	Date	Transect	Date
1	6 April	10	5 April	19	12 April	28	23 April
2	6 April	11	2 April	20	12 April	29	2 July
3	10 April	12	9 April	21	19 April	30	2 July
4	10 April	13	4 April	22	20 April	31	4 July
5	3 April	14	3 April	23	20 April	32	4 July
6	3 April	15	10 April	24	21 April	33	3 May
7	4 April	16	10 April	25	24 April	34	3 May
8	4 April	17	11 April	26	24 April		
9	5 April	18	12 April	27	23 April		

Transect monitoring dates in 2002:

Transect	Date	Transect	Date	Transect	Date	Transect	Date
1	16 April	10	13 April	19	29 April	28	25 April
2	8 April	11	13 April	20	15 April	29	24 April
3	16 April	12	13 April	21	15 & 17	30	24 April
4	16 April	13	14 April	22	15 April	31	24 April
5	11 April	14	14 April	23	24 April	32	24 April
6	11 April	15	18-19 April	24	3 May	33	23 April
7	11 April	16	25 April	25	25 April	34	23 April
8	12 April	17	29 April	26	25 April		
9	12 April	18	29 April	27	25 April		

Bar Graphs of Mean Transect Abundance Class Totals and Mean Number of Occupied Cells per Transect

Figures 1-6 are bar graphs showing mean transect abundance class totals and mean number of occupied cells/transect for *Astragalus magdalenae* var. *peirsonii*, *Helianthus niveus* var. *tephrodes*, and *Pholisma sonorae* for 1977, 1998, 1999, 2000, 2001, and 2002. The graphs were generated using the program SYSTAT, version 10.2 (SYSTAT Software Inc. 2002). Figures 1, 3, and 5 show mean total abundance class values for each of the three species, respectively, while figures 2, 4, and 6 show the mean number of cells/transect occupied by each of the three species, respectively. Mean total abundance class values were calculated by adding the abundance class values for each of the cells along a transect, using that total value to characterize the transect, and then taking the mean of all the transect totals for each area (entire dunes, closed area, and open area). The mean number of occupied cells/transect was calculated by simply counting the number of cells along each transect occupied by the species (without regard to abundance class value) and then taking the mean number of occupied cells/transect for each area (entire dunes, closed area, and open area). Error bars corresponding to 95% confidence intervals are shown for both mean total abundance class values and mean number of occupied cells/transect.

The graphs of the mean numbers of occupied cells/transect can be used to "validate" the patterns observed in the graphs of mean transect abundance class totals. This is necessary because an abundance class total for a particular transect could be the result of one to few cells having large abundance class values or many cells having abundance class values of 1. To see why this is important, consider the following (hypothetical) example. Transect X may have an abundance class total of 8 for *Astragalus magdalenae* var. *peirsonii*, this resulting from 8 cells all occupied by the species, each having an abundance class value of 1. Because abundance class 1 represents a range of 1-10 individuals, the range of individuals encountered in the entire transect would be 8-80 (8 if only one individual were encountered in each cell, 80 if 10 individuals were encountered in each cell). Transect Y may also have an abundance class total of 8, this resulting from only 2 cells occupied by the species, each having an abundance class value of 4. Because abundance class value 4 represents a range of 1001-10,000 individuals, the range of individuals encountered in the entire transect would be 2002-20,000 individuals. Transects X and Y are obviously quite different in terms of distribution and abundance of *Astragalus magdalenae* var. *peirsonii*, but they are considered the same in the analysis of mean transect abundance class totals. If, however, bar graphs of mean transect abundance class totals and mean numbers of occupied cells/transect show similar patterns, then it is unlikely that the extremes illustrated in this hypothetical example are coming into play, and one feels comfortable using the mean abundance class totals. As illustrated by the following pairs of graphs for each species, the patterns are remarkably consistent for the two types of measurement (note that it is the *patterns* that are similar—the actual values for the mean transect abundance class totals will always be at least as high or higher than the mean number of occupied cells/transect). Thus, it appears entirely appropriate to use the mean abundance class totals in the analysis and interpretation of the data.

Another potential issue in using the mean abundance class totals for 1977 is that WESTEC used a different rating system for placing cells into abundance classes than BLM used in its 1998-

2002 monitoring. Though this may have an effect on the comparisons between the 1977 mean abundance class totals and those from 1998-2002, the comparisons were made anyway, based on the assumption that the WESTEC ratings would not have been much different had they employed the BLM rating system in 1977. There is no similar issue with regard to the use of mean number of cells occupied per transect, because no rating was involved in any of the years—either one or more plants was present in a cell or not. The analysis and interpretation contained in this report is based on both data sets, the mean abundance class totals and the mean number of occupied cells/transect.

Although separate bars are given for the "open" area in the graphs below, readers should bear in mind that, because of the interim closures in the areas formerly designated as open, 2001 and 2002 transect data for the "open area" represent a combination of areas actually open to OHV use and areas closed on an interim basis to OHV use.

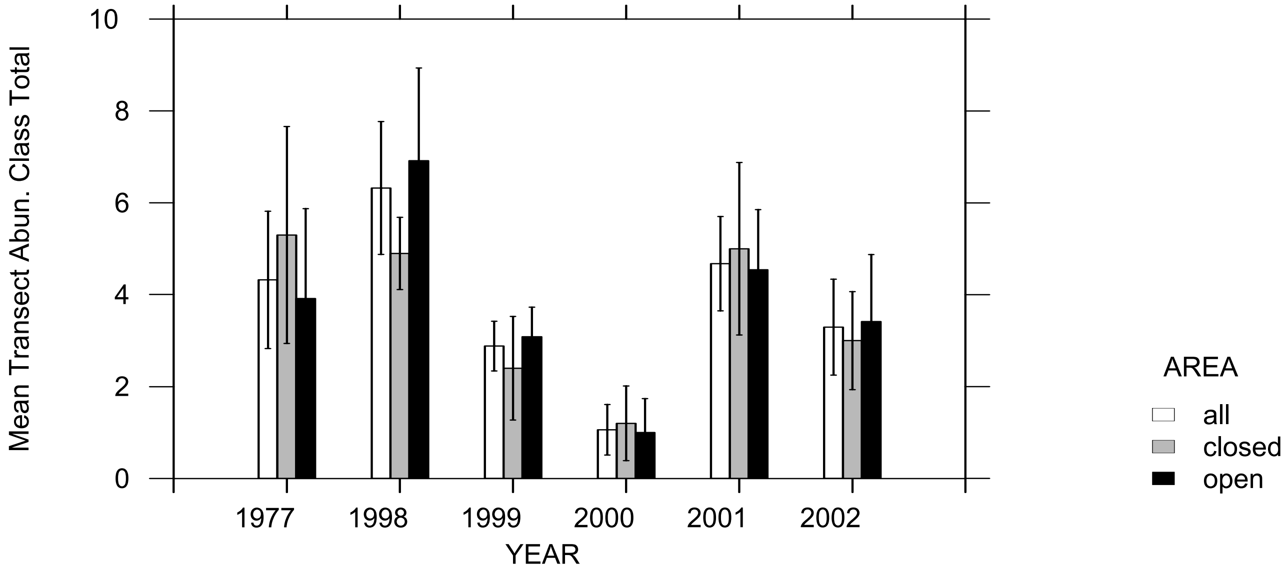

Figure 1. *Astragalus magdalenae* var. *peirsonii* mean transect abundance class totals for the entire dunes ("all"), for the closed area, and for the open area. Error bars are 95% confidence intervals.

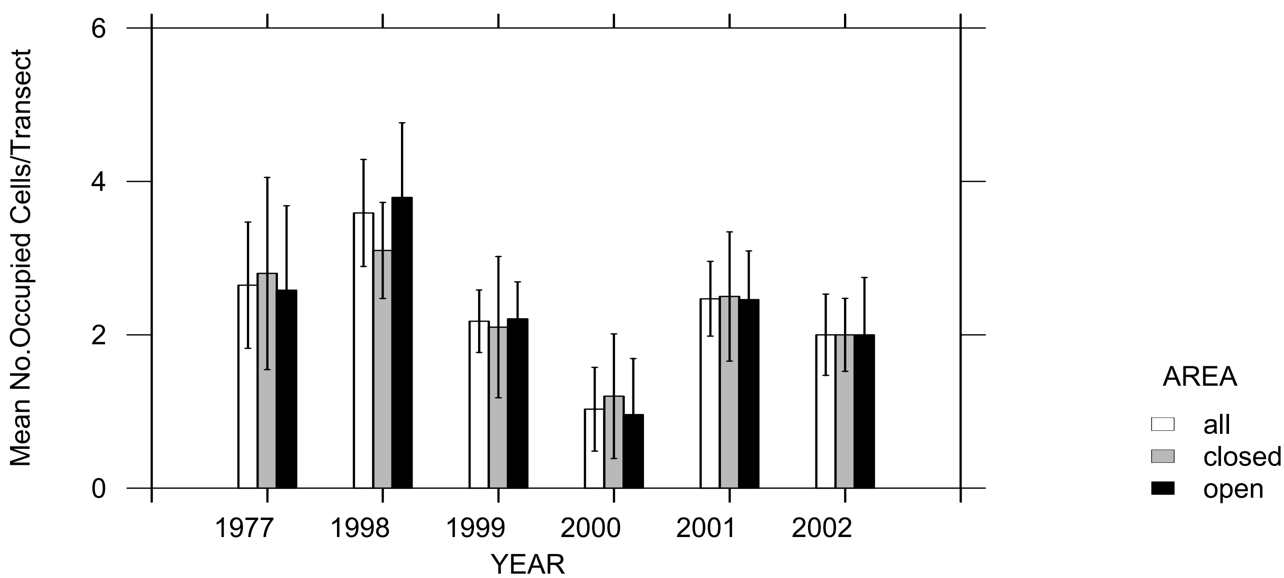

Figure 2. Mean number of cells/transect occupied by *Astragalus magdalenae* var. *peirsonii* in the entire dunes ("all"), in the closed area, and in the open area. Error bars are 95% confidence intervals.

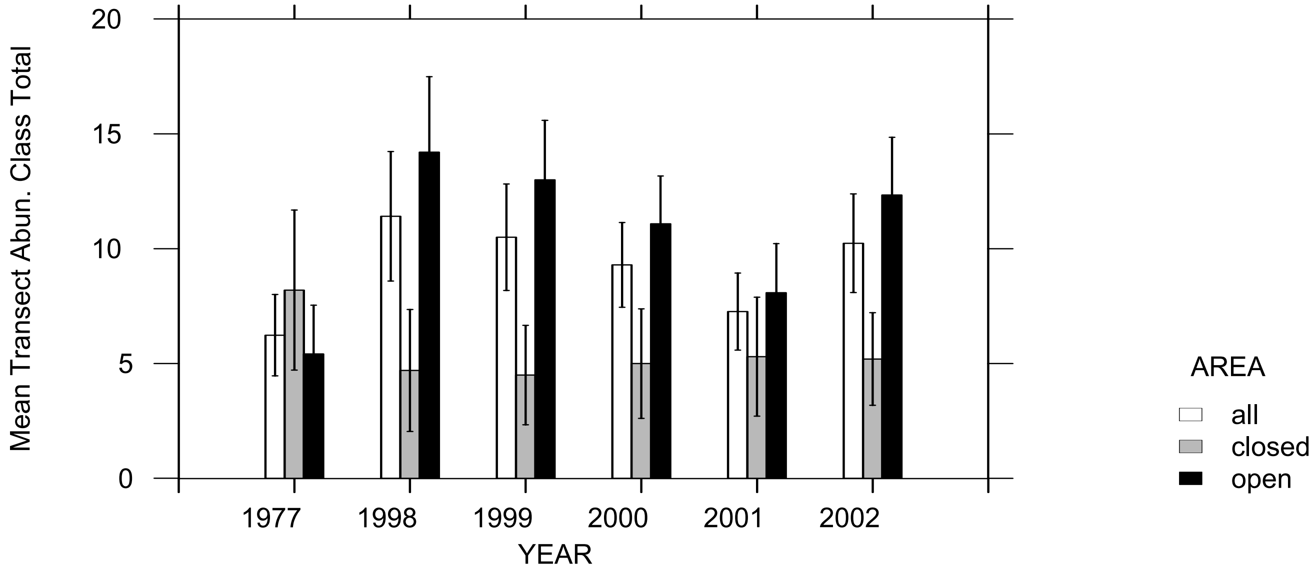

Figure 3. *Helianthus niveus* ssp. *tephrodes* mean transect abundance class totals for the entire dunes ("all"), for the closed area, and for the open area. Error bars are 95% confidence intervals.

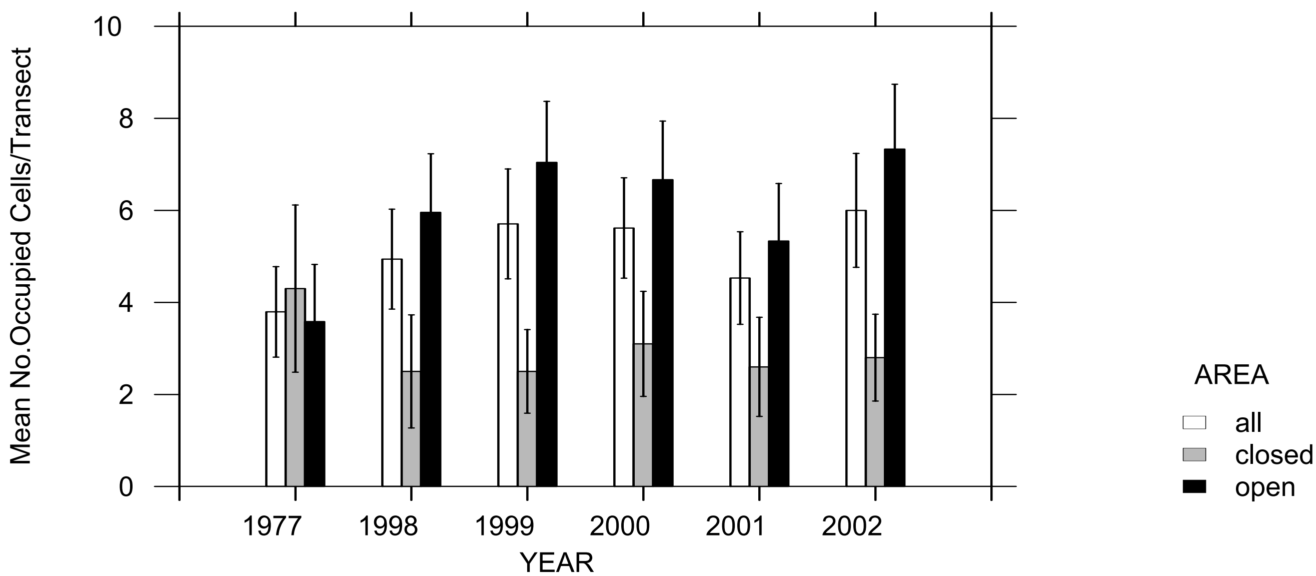

Figure 4. Mean number of cells/transect occupied by *Helianthus niveus* ssp. *tephrodes* in the entire dunes ("all"), in the closed area, and in the open area. Error bars are 95% confidence intervals.

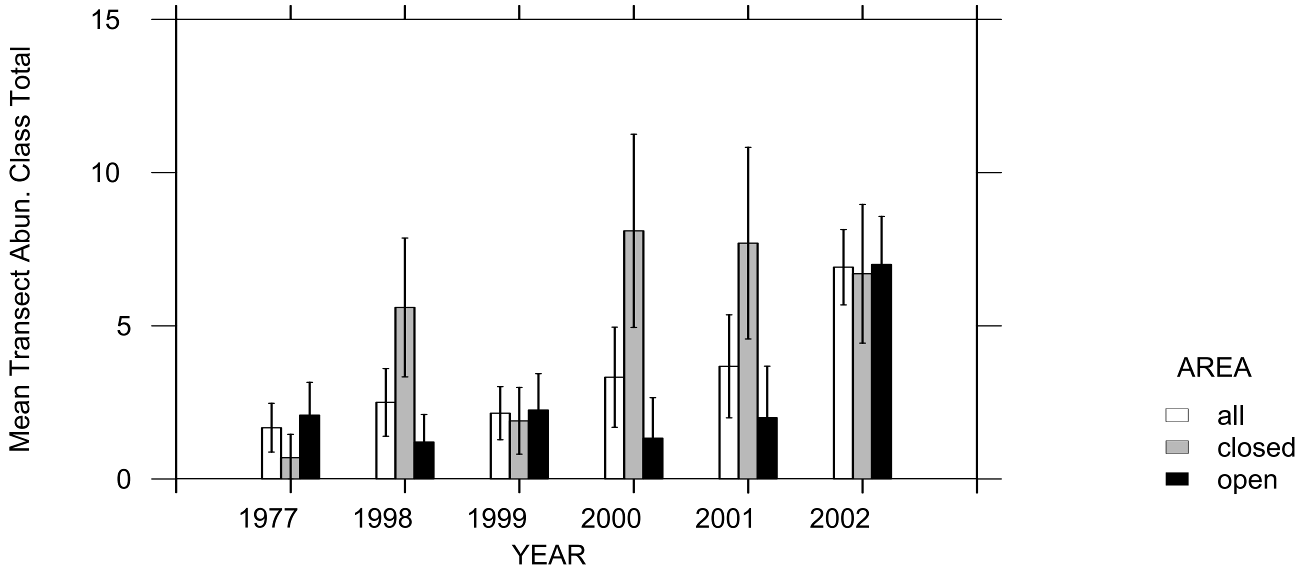

Figure 5. *Pholisma sonorae* mean transect abundance class totals for the entire dunes ("all"), for the closed area, and for the open area. Error bars are 95% confidence intervals.

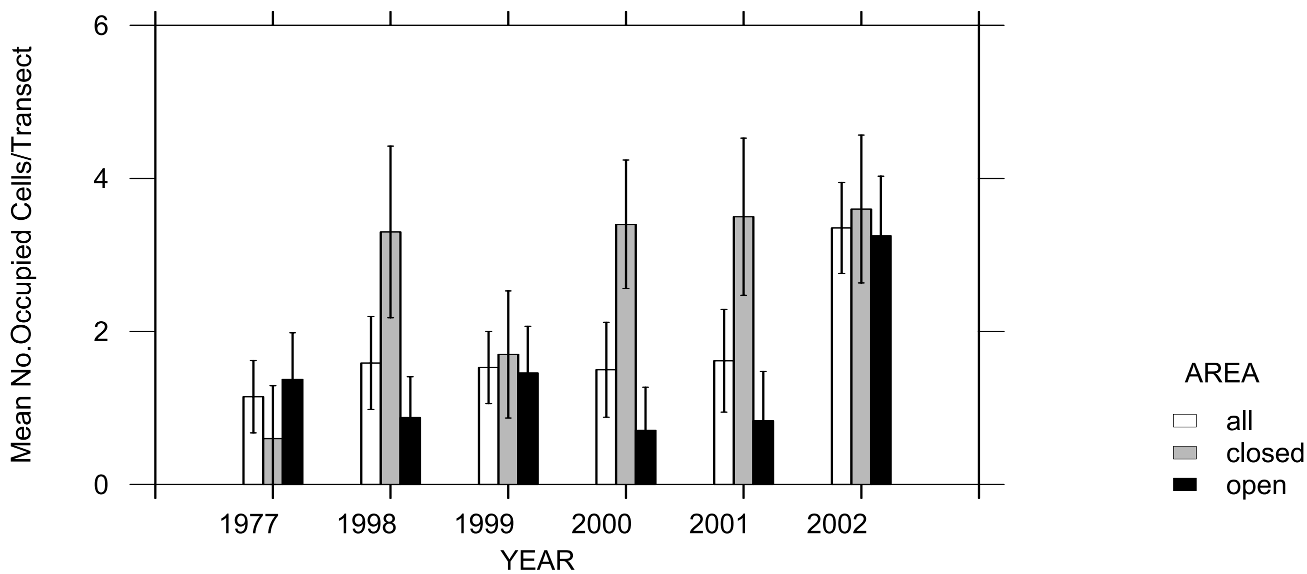

Figure 6. Mean number of cells/transect occupied by *Pholisma sonorae* in the entire dunes ("all"), in the closed area, and in the open area. Error bars are 95% confidence intervals.

Growing Season Precipitation

WRCC Weather Stations. Table 1 shows the precipitation for each of the six growing seasons preceding monitoring for each of the seven stations in the vicinity of the dunes. Also included are the growing season averages of all stations, of those stations west of the dunes (Brawley, El Centro, and Imperial), and of those stations east of the dunes (Gold Rock Ranch, Yuma WSO Airport, Yuma Citrus Station, and Yuma Proving Ground). Table 2 shows the long-term mean annual precipitation for all recorded years for each station. Table 3 shows the percent of the long-term mean growing season precipitation for each growing season, each station, and the average of all stations. Figure 7 shows the average growing season precipitation between 1964 and 2003 (averaged across all stations listed below). As the figure shows, only two of the last 10 growing seasons have experienced precipitation higher than the long-term average.

Table 1. Growing season precipitation for each of the seven weather stations in the vicinity of the Algodones Dunes for the six growing seasons preceding monitoring.

Weather Station	Growing Season Precipitation (inches)					
	1976-1977	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002
Brawley 2 SW	5.42	4.23	0.34	0.46	1.35	0.00
El Centro	3.26	4.8	0.85	1.03	1.9	0.05
Gold Rock Ranch	5.26	No data	No data	No data	No data	No data
Imperial	3.97	4.99	2.06	1.53	2.33	0.01
Yuma WSO Airport	2.06	No data	No data	No data	No data	No data
Yuma Citrus Station	2.54	9.03	No data	1.30	No data	No data
Yuma Proving Ground	4.95	7.53	2.69	1.29	5.04	0.44
Average of all stations	3.92	6.12	1.49	1.12	2.66	0.13
Average of stations west of dunes	4.22	4.67	1.08	1.01	1.86	0.02
Average of stations east of dunes	3.70	8.28	2.69	1.30	5.04	0.44

Table 2. Period of record mean annual precipitation for each of the seven weather stations in the vicinity of the Algodones Dunes.

Weather Station	Period of Record	Long-term Mean Annual Precipitation (inches)
Brawley 2 SW	1927-2003	2.67
El Centro	1948-2003	2.71
Gold Rock Ranch	1964-1996	3.89
Imperial	1948-2003	2.61
Yuma WSO Airport	1948-2003*	3.02
Yuma Citrus Station	1920-2003*	3.49
Yuma Proving Ground	1958-2003	3.73
Average of all stations		3.16
Average of stations west of dunes		2.66
Average of stations east of dunes		3.53

* Although this is the official period of record as given by the Western Regional Climate Center, Yuma WSO Airport has been very sporadic in its collection of rainfall data since 1997 and Yuma Citrus Station since 1998.

Table 3. Percent of long-term mean precipitation by growing season for the seven weather stations in the vicinity of the Algodones Dunes.

Weather Station	Percent of Long-Term Mean Precipitation by Growing Season					
	1976-1977	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002
Brawley 2 SW	203%	158%	13%	17%	51%	0%
El Centro	120%	177%	31%	38%	70%	2%
Gold Rock Ranch	135%	No data	No data	No data	No data	No data
Imperial	152%	191%	79%	59%	89%	0%
Yuma WSO Airport	68%	No data	No data	No data	No data	No data
Yuma Citrus Station	73%	259%	No data	37%	No data	No data
Yuma Proving Ground	133%	202%	72%	35%	135%	12%
Average	126%	197%	49%	37%	86%	4%

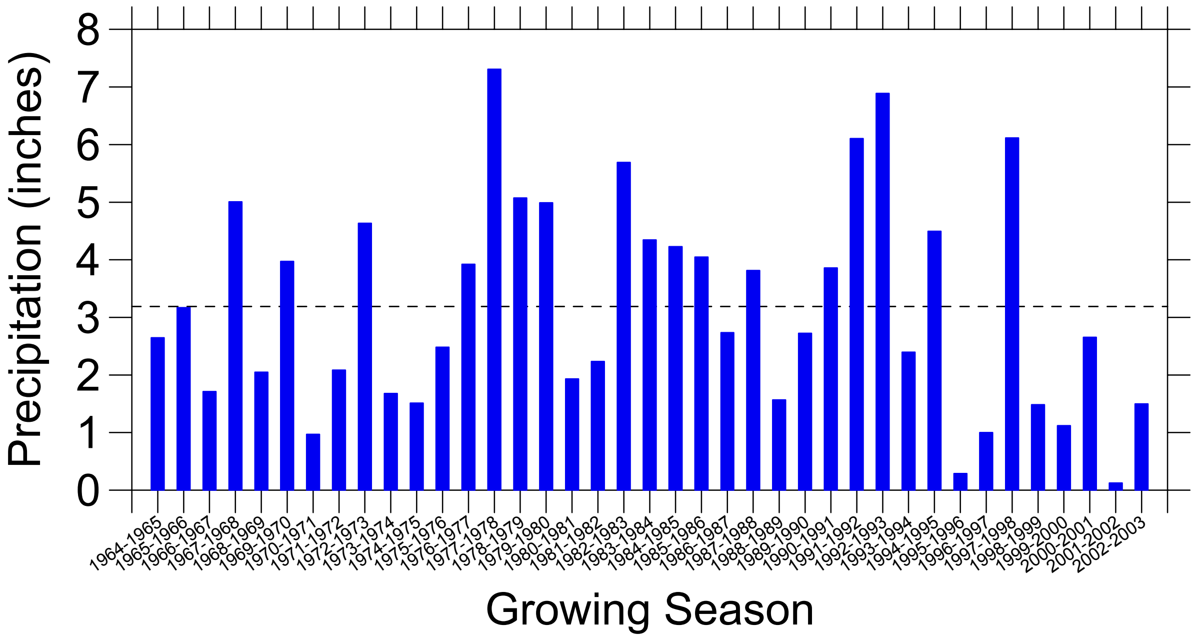

Figure 7. Growing season precipitation averaged across the seven weather stations in the vicinity of the Algodones Dunes between 1964 and 2003. The dashed line is the overall average growing season precipitation for the period. As the graph shows, 8 of the last 10 growing seasons have experienced below average precipitation.

Remote Area Weather Stations (RAWS). Table 4 shows the growing season precipitation collected by the two RAWS stations in the dunes. For the 2001-2002 growing season, note the large difference between the precipitation totals for the two RAWS stations, as well as the large difference between the average of the two RAWS stations (1.83 inches) and the average of the WRCC stations (0.13 inches). Most of the difference between the two RAWS stations is the result of a single storm event on August 8, 2001, that dropped precipitation in the southern part of the Dunes (at Buttercup) but not in the northern part of the Dunes. Because this storm also did not drop precipitation on any of the WRCC stations, this storm event is also a major reason for the difference between the RAWS average and the WRCC average.

Table 4. Growing season precipitation from the two remote area weather stations (RAWS) in the Algodones Dunes. The growing season precipitation averaged across the WRCC stations in the vicinity of the dunes is given for comparison. All units are in inches.

Growing Season	Cahuilla RAWS	Buttercup RAWS	Average of the two RAWS	Average of all WRCC Stations
2000-2001*	1.41	2.65	2.03	2.66
2001-2002	0.98	2.68	1.83	0.13

* Growing season precipitation from the RAWS stations is incomplete for this growing season because the stations did not begin collecting data until November 16, 2000.

Monthly precipitation by growing season. Figures 20-25 in Appendix 1 show monthly precipitation as recorded by WRCC weather stations for the 1976-1977, 1997-1998, 1998-1999, 1999-2000, 2000-2001, and 2001-2002 growing seasons. Figures 26-27 in Appendix 1 show monthly precipitation as recorded by the RAWS for 2000-2001 and 2001-2002 (data for the 2000-2001 growing season include only the period between the establishment of the stations on November 16, 2000, and June 30, 2001).

Response of Species to Precipitation

Figures 8-13 show the mean transect abundance class totals and mean number of occupied cells/transect, respectively, for each of the three species plotted against growing season precipitation. Table 5 shows the precipitation data sets that were used to create the precipitation lines shown in the figures.

Table 5. Precipitation data sets used to construct the precipitation lines shown in Figures 8-13. Growing season precipitation is the total amount of precipitation that fell between July and June immediately preceding the monitoring. So, for example, the growing season precipitation for 1977 is the amount that fell between July 1976 and June 1977. See the methods section for more details.

Year	Precipitation Data Set
1977	Average of the following weather stations: Brawley 2 SW, El Centro, Gold Rock Ranch, Imperial, Yuma WSO Airport, Yuma Citrus Station, and Yuma Proving Ground
1998	Average of Brawley 2 SW, El Centro, Imperial, Yuma Citrus Station, and Yuma Proving Ground
1999	Average of Brawley 2 SW, El Centro, Imperial, and Yuma Proving Ground
2000	Average of Brawley 2 SW, El Centro, Imperial, Yuma Citrus Station, and Yuma Proving Ground
2001	July and August: Average of Brawley 2 SW, El Centro, Imperial, Yuma Citrus Station, and Yuma Proving Ground September-October: Average of Brawley 2 SW, El Centro, Imperial, and Yuma Proving Ground November: Average of Brawley 2 SW, El Centro, Imperial, Yuma Citrus Station, and Yuma Proving Ground December-June: Average of Buttercup and Cahuilla RAWS
2002	Average of Buttercup and Cahuilla RAWS

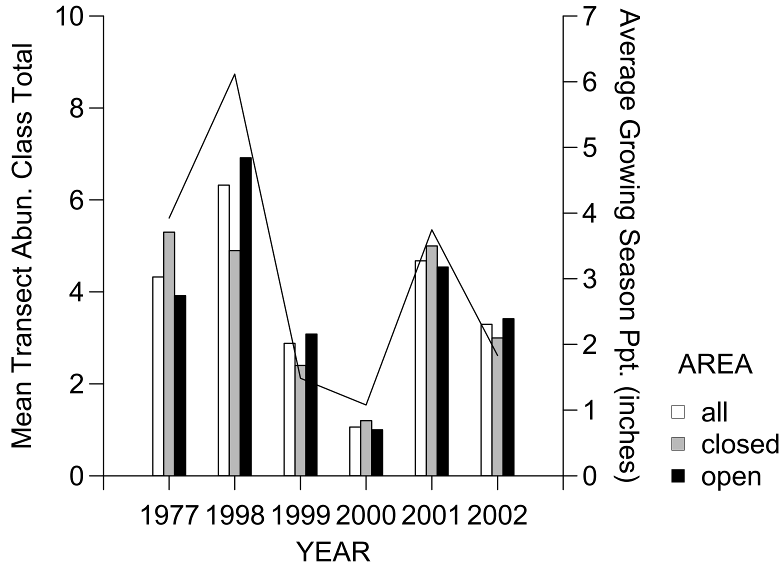

Figure 8. Mean transect abundance class totals for *Astragalus magdalenae* var. *peirsonii* (bars and left y-axis) plotted against mean growing season precipitation (line and right y-axis). Area: all = entire dunes; closed = wilderness area (closed to OHV use); and open = all areas outside of wilderness (open to OHV use).

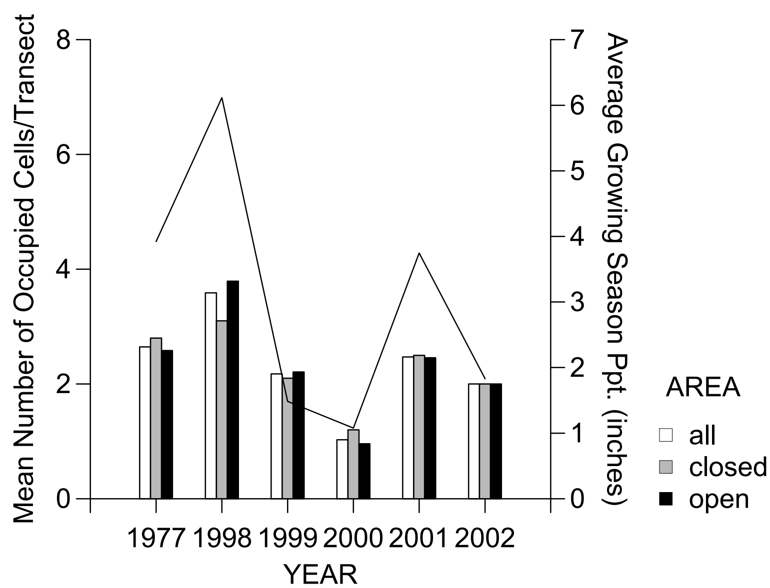

Figure 9. Mean number of occupied cells/transect for *Astragalus magdalenae* var. *peirsonii* (bars and left y-axis) plotted against mean growing season precipitation (line and right y-axis). Area: all = entire dunes; closed = wilderness area (closed to OHV use); and open = all areas outside of wilderness (open to OHV use).

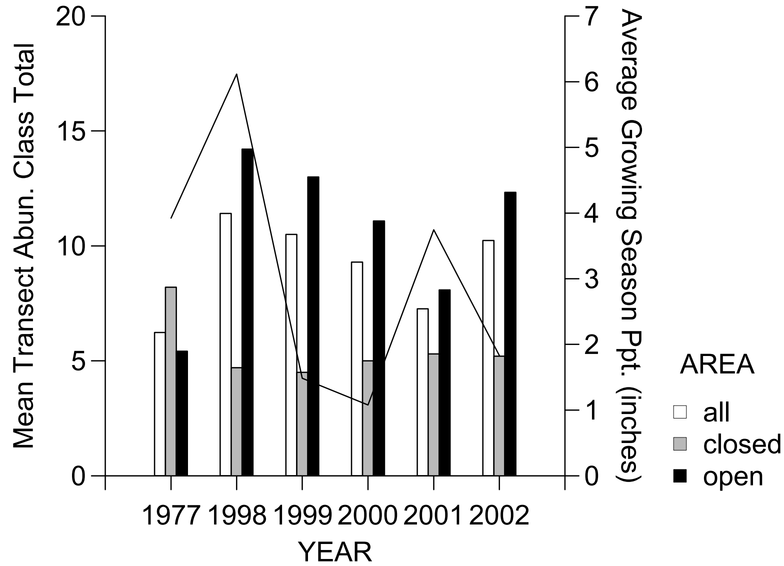

Figure 10. Mean transect abundance class totals for *Helianthus niveus* ssp. *tephrodes* (bars and left y-axis) plotted against mean growing season precipitation (line and right y-axis). Area: all = entire dunes; closed = wilderness area (closed to OHV use); and open = all areas outside of wilderness (open to OHV use).

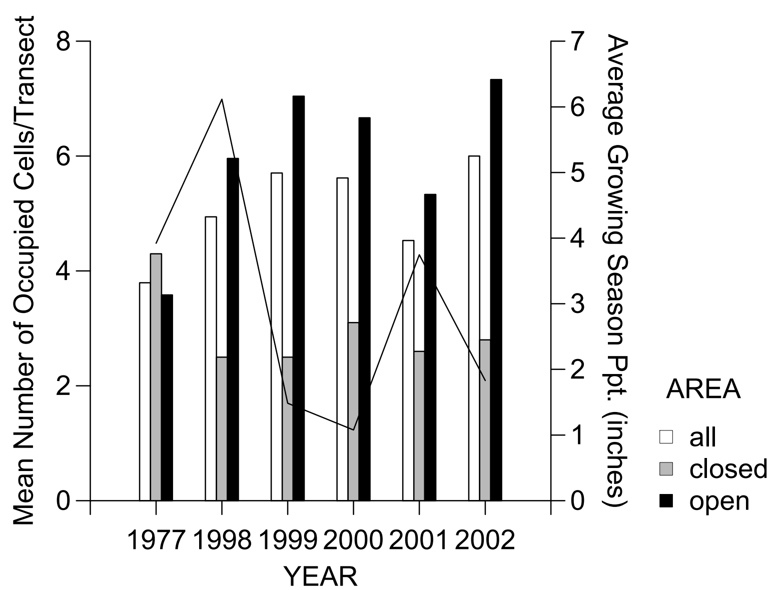

Figure 11. Mean number of occupied cells/transect for *Helianthus niveus* ssp. *tephrodes* (bars and left y-axis) plotted against mean growing season precipitation (line and right y-axis). Area: all = entire dunes; closed = wilderness area (closed to OHV use); and open = all areas outside of wilderness (open to OHV use).

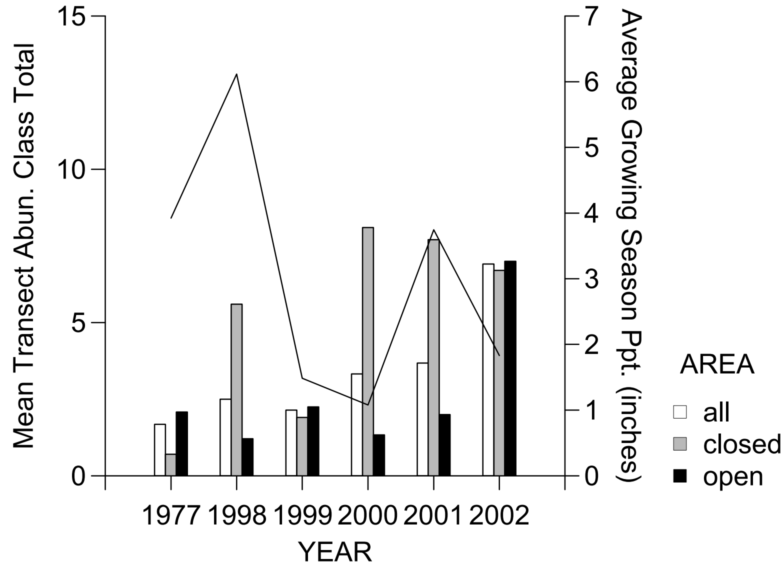

Figure 12. Mean transect abundance class totals for *Pholisma sonorae* (bars and left y-axis) plotted against mean growing season precipitation (line and right y-axis). Area: all = entire dunes; closed = wilderness area (closed to OHV use); and open = all areas outside of wilderness (open to OHV use).

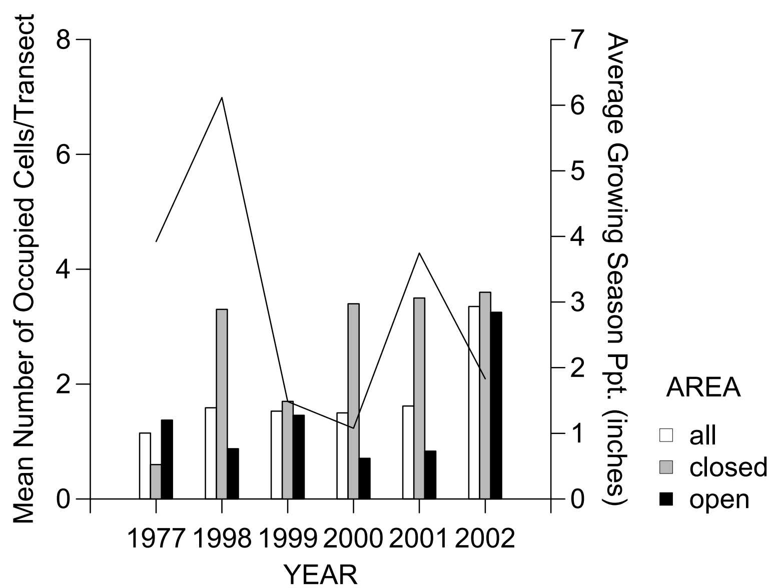

Figure 13. Mean number of occupied cells/transect for *Pholisma sonorae* (bars and left y-axis) plotted against mean growing season precipitation (line and right y-axis). Area: all = entire dunes; closed = wilderness area (closed to OHV use); and open = all areas outside of wilderness (open to OHV use).

Percent seedling plants. Table 8 (in Appendix 1) shows the number of seedlings and adult plants tallied along transects in 1998, 1999, 2000, 2001, and 2002 for ASMAP and HENIT. Table 9 (Appendix 1) shows the percentage of total plants tallied in each of those years that were seedlings. Only 1% of the ASMAP plants tallied in 1998 were seedlings; the remainder were adult, flowering plants. This is presumably because all of the first year plants germinated in response to significant rainfall events in September and December 1997 (Figure 21) and had sufficient time to reach the flowering stage by the time monitoring began in April 1998. Another significant rainfall event in February 1998 (Figure 21) might have been expected to result in a flush of seedlings that would not yet have reached the flowering stage by April 1998. What ASMAP seedlings were tallied in 1998 probably were part of the February cohort. Seedlings amounted to 4.2% of the total plants in the closed area; though only 0.5% of the plants tallied in the open area were seedlings, this percentage would probably have been higher had the open area been sampled in April. Because of mechanical problems associated with vehicles, most of the open area was not sampled until summer 1998, at which time the February cohort would either have flowered or senesced.

No ASMAP seedlings were tallied in either 1999 or 2000. Both of these years were low precipitation years, and consequently there much lower numbers of tallied plants than in 1998 (942 plants were tallied along all of the transects in 1999 and only 86 in 2000). It is possible that no plants germinated in either year and that the flowering plants counted were the result of the 1998 cohort. In 2001 and 2002 the percentages of seedling plants were higher than in 1998 (12.5% and 6.7%, respectively). The 2001 seedlings were likely the product of rainfall events in February and March 2001 (Figures 24 and 26). The remaining adult, flowering plants were likely the result of a rainfall event in October 2000 (Figure 24). Most of the 2002 seedlings were observed in the open area in the southern part of the dunes, but there is no precipitation event clearly responsible for the seedlings observed. The last significant precipitation recorded by the Buttercup RAWS station was in October 2001 (Figure 27). Though the adult plants observed in the southern open area were likely products of the October 2001 rainfall event, it seems unlikely that any plants from the October 2001 cohort would still have been seedlings at the time of monitoring. There were two minor precipitation events recorded at the Cahuilla RAWS in November and December (Figure 27), but plants growing in response to these events probably would have been flowering by the time of monitoring. Perhaps the 2002 seedlings were the result of a localized rainfall event in late January to early March that did not include the areas where the two RAWS occur. The fact that 117 of the 154 seedlings tallied throughout the dunes in 2002 were found in a single cell along Transect 17 in the northern half of the southern open area lends some support to this contention (there is further discussion on this issue below).

Comparison of Closed and Open Areas

Abundance class and number of occupied cells/transect. Comparisons between the closed and open areas similar to those given in Willoughby (2001) are given here for the sake of consistency with the previous report. As previously stated, however, these comparisons are no longer as “clean” as they were in the previous report because part of the area that was open to OHVs in 1977, 1998, 1999, and 2000 was closed in 2001 and 2002 in accordance with a lawsuit settlement. Thus, the area considered “open” for 2001 and 2002 consists of areas that remained open to OHV use and areas closed for those two years. Also, as pointed out in Willoughby

(2001), this is a monitoring program, not research. Consequently, there are limitations in using these data to infer cause and effect with respect to OHV use.

Figures 14 and 15 show the responses of mean transect abundance class and mean number of occupied cells/transect, respectively, of ASMAP in the open and closed areas over the 6 years monitored. The remaining pairs of figures (16 and 17; 18 and 19) provide similar information for HENIT and PHSO, respectively.

Multivariate repeated-measures analyses of variance were performed on both the mean transect abundance class totals and the mean number of occupied cells/transect for each of the species. For ASMAP the year x area interaction effect on mean transect abundance class totals is not significant (Pillai's trace test statistic, $P = 0.414$), leading to acceptance of the null hypothesis that the response of the species over the years monitored was similar (parallel) in both the closed and open areas. This is consistent with the findings in Willoughby (2001) for the years 1977, 1998, 1999, and 2000. The same analysis on mean number of occupied cells/transect also shows the year x area interaction effect to be not significant (Pillai's trace test statistic, $P = 0.901$), again supporting the conclusion that the species' response in the two areas is parallel, which figures 14 and 15 strongly suggested.

For the other two species the year x area interaction effects were significant for both the mean transect abundance class totals and the mean number of occupied cells/transect, leading to rejection of the null hypothesis that the responses of these variables were similar in the closed and open areas (Pillai's trace test statistic, $P = 0.001$ and $P = 0.001$ for HENIT abundance and occupied cells/transect, respectively, and $P = 0.000$ and $P = 0.001$ for PHSO abundance and occupied cells/transect, respectively).

Thus, while ASMAP exhibited parallel responses between the closed and open areas, HENIT and PHSO did not.

Percent seedling plants. Table 9 shows the percent seedling plants for ASMAP and HENIT by year in the closed area, the open area, and the entire dunes. For ASMAP, the seedling percentages vary significantly between the closed and open areas in 1998, 2001, and 2002. In 1999 and 2000 there were no seedlings observed in either the open or closed areas. In 1998 there was a higher percentage of seedlings in the closed area (4.2%) than in the open area (0.5%); this difference was likely due to the fact that in 1998, because of mechanical problems with vehicles, most of the open area transects were read at much later dates than the closed area transects. In 2001 and 2002, there were higher seedling percentages in the open area (13.8% and 8.2% respectively) than in the closed area (10.9% and 0.9%, respectively). The difference in 2001 may result from the fact that the southern, open part of the dunes received more precipitation than the northern, closed part of the dunes (Table 4 and Figure 26). November 2000-June 2001 precipitation at the Cahuilla RAWS station in the northern part of the dunes was 1.41 inches, whereas precipitation at the Buttercup RAWS station in the southern dunes was 2.65 inches over that same period (Table 4). In addition, almost 1.4 inches of precipitation fell at Buttercup in March 2001, compared with 0.6 inches at Cahuilla during March (Figure 26). Most of the seedling plants counted in spring 2001 likely came from the March rains, and a larger number of seedlings would be expected in response to the heavier March rainfall in the southern dunes. In

2002 the higher percentage of seedlings in the open area may also have resulted from heavier rainfall in the southern dunes as reflected in the 2001-2002 growing season totals for the two RAWS stations (0.98 inches recorded at Cahuilla, 2.68 inches at Buttercup), but most of the Buttercup precipitation fell in August 2001 (1.9 inches) and October 2001 (0.7 inches). Plants germinating during either of those months would be classified as adults during spring 2002. It should be noted that only 154 out of a total of the 2,297 plants tallied in 2002 were classified as seedlings (6.7%). An inspection of the raw transect data shows that 120 of the 154 seedlings were counted along a single belt transect (Transect 17; 117 seedlings were recorded in a single cell along this transect). Why this one transect alone would have more than 75% of all of the seedlings observed in 2002 is unclear, but may be the result of a very localized storm event. It likely is not the result of observer misclassification, since the same observer read several other transects near the same date as Transect 17.

For HENIT, the years 1998 and 2001 were the most successful for production of seedlings. The very large 1998 difference between the percentage of seedlings in the closed and open areas (48.7% and 2.1%, respectively) is probably largely due to the fact that the transects for most of the open area were read much later in the year than those in the closed area (see discussion above for ASMAP). The 2001 difference between the percentage of seedlings in the closed and open areas (52.3% and 25.6%, respectively) is harder to account for. It is hard to invoke an explanation relative to differential amounts of rainfall between the northern and southern dunes, because there was a higher percentage of seedlings in the northern, closed area, which--according to the RAWS data discussed above under ASMAP--received less rainfall than the southern, open area. Environmental variables in addition to rainfall, such as temperature or sand particle size, may be important to HENIT seed germination. In 1999 and 2002, though the dune-wide percentages of seedlings were lower than in 1998 and 2001, there were higher percentages of seedlings in the open area than in the closed area—the opposite pattern to that observed in 1998 and 2001.

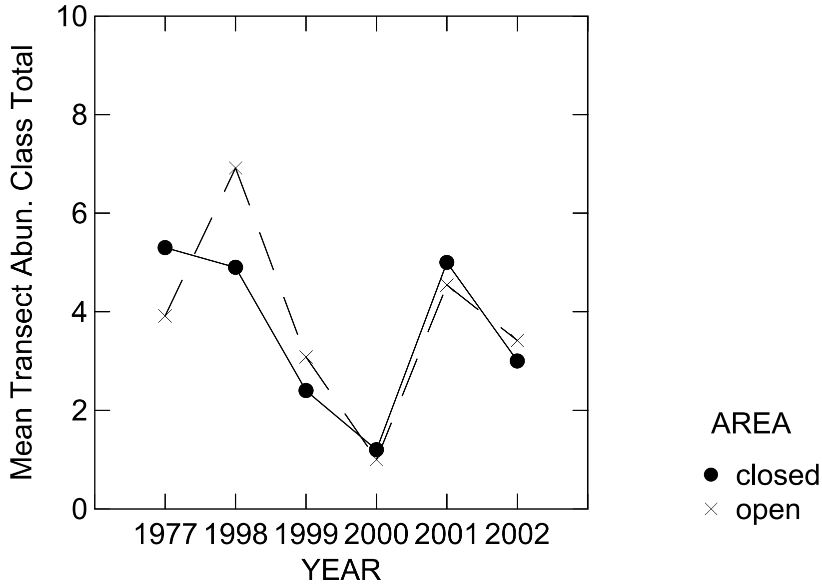

Figure 14. Comparison of ASMAP mean transect abundance class totals for the closed and open areas over the 6 years in which monitoring studies were conducted.

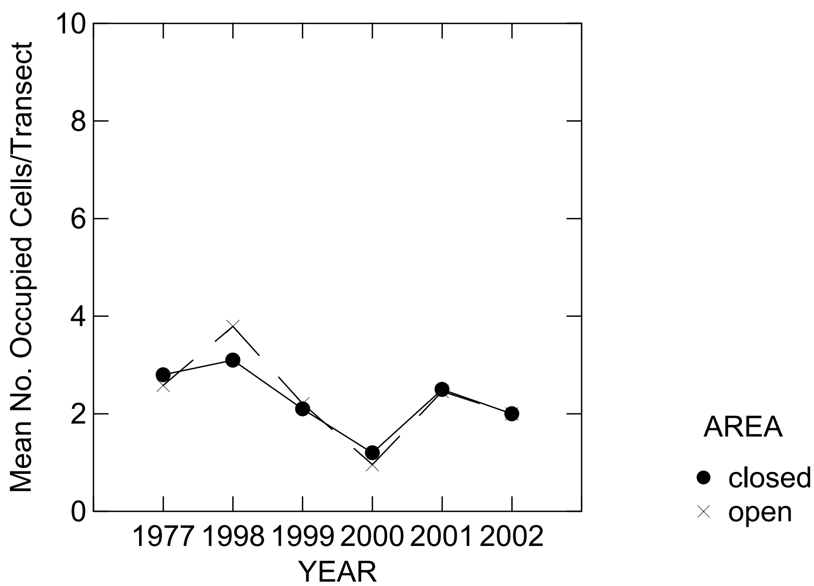

Figure 15. Comparison of ASMAP mean number of occupied cells/transect for the closed and open areas over the 6 years in which monitoring studies were conducted.

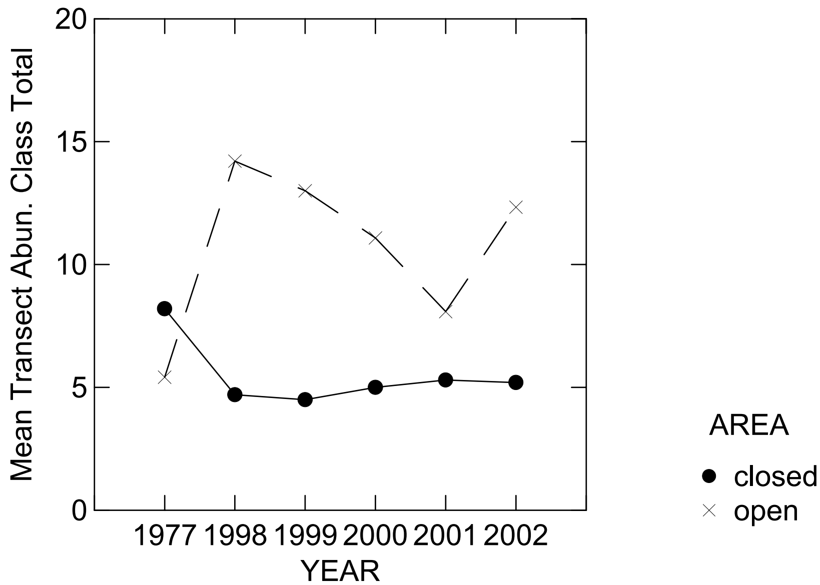

Figure 16. Comparison of HENIT mean transect abundance class totals for the closed and open areas over the 6 years in which monitoring studies were conducted.

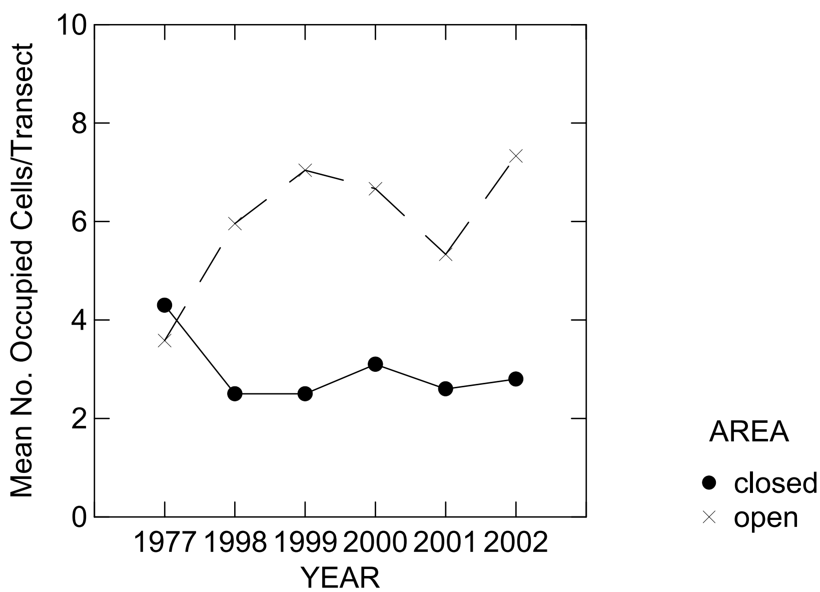

Figure 17. Comparison of HENIT mean number of occupied cells/transect for the closed and open areas over the 6 years in which monitoring studies were conducted.

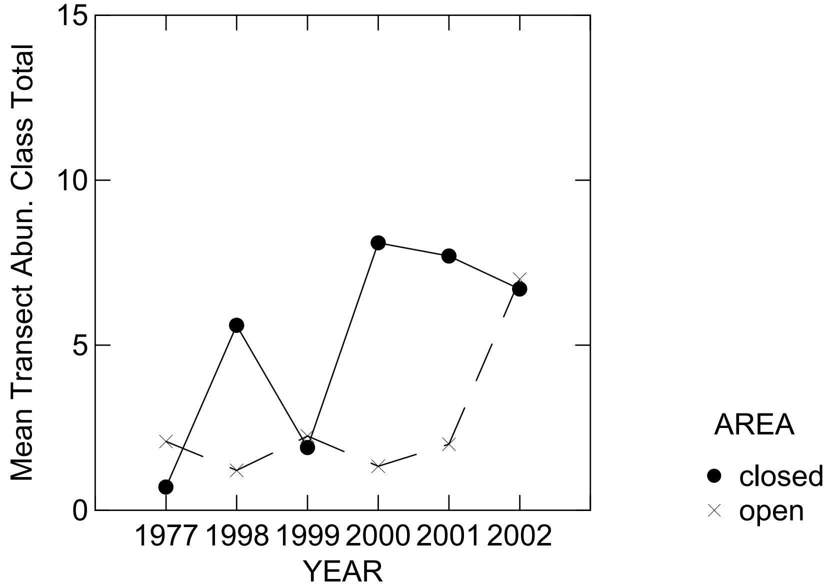

Figure 18. Comparison of PHSO mean transect abundance class totals for the closed and open areas over the 6 years in which monitoring studies were conducted.

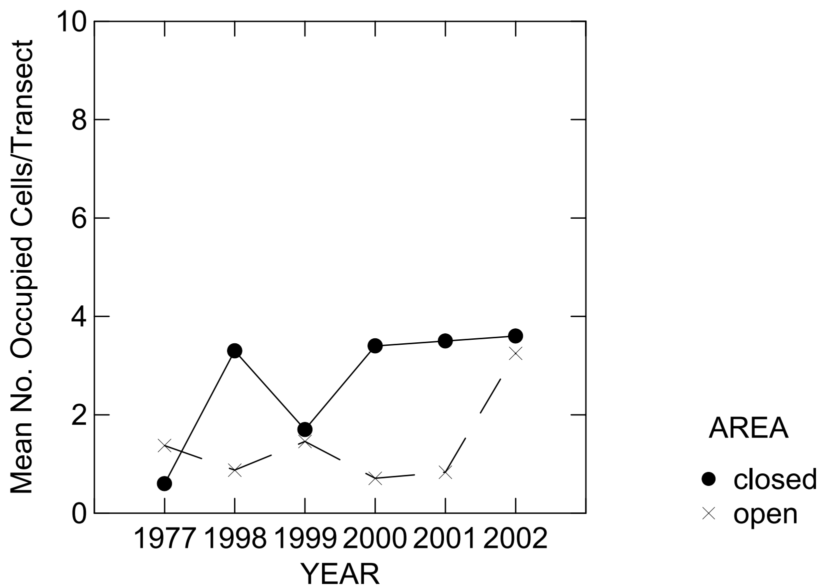

Figure 19. Comparison of PHSO mean number of occupied cells/transect for the closed and open areas over the 6 years in which monitoring studies were conducted.

Discussion

Astragalus magdalenae* var. *peirsonii

As Figure 8 shows, ASMAP abundance closely tracks the precipitation in the growing season immediately preceding monitoring. Regression analysis of ASMAP abundance on growing season precipitation yields coefficients of determination (r^2 values) of 0.89, 0.73, and 0.88, respectively, for the entire dunes, the closed (wilderness) area, and the open area ("open area" is used here to include all of the dunes that were open to OHV use prior to the recent interim closures). These are very similar to the values computed in Willoughby (2001) for the four years 1977, 1998, 1999, and 2000 (r^2 values for these four years were 0.91, 0.79, and 0.88, respectively for the entire dunes, the closed area, and the open area). Thus, the addition of two more years of data lends stronger support to the conclusion that this species responds much more like an annual than a perennial. The response of ASMAP mean number of occupied cells/transect is similar to that of the abundance class data, also closely tracking growing season precipitation (Figure 9; r^2 values are 0.85, 0.82, and 0.70, respectively, for the entire dunes, the closed area, and the open area).

Abundance values within each year between the dunes as a whole, the closed area, and the open area are similar (Figures 1 and 14), as are the number of occupied cells/transect (Figures 2 and 15), and statistical analysis supports the hypothesis that the responses of these variables are parallel between the closed and open areas. This indicates that there has been little change in Peirson's milk-vetch abundance and distribution in the open area relative to the closed area since 1977. Changes in year-to-year abundance are related primarily to weather in both the open and closed areas.

Thus, the addition of two more years of monitoring data continue to support the conclusions of the Willoughby (2001) report that populations of Peirson's milk-vetch continue to remain healthy in the open area, although the data for the "open area" in 2001 and 2002 include data collected from areas that have continued to remain open to OHV use combined with areas that have been closed to OHV use on an interim basis.

Helianthus niveus* ssp. *tephrodes

HENIT abundance does not track growing season precipitation at all (r^2 values are 0.00, 0.04, and 0.00, for the entire dunes, the closed area, and the open area, respectively). This is presumably due to its being a much longer-lived perennial than ASMAP. Thus, a relatively large percentage of established plants persist through poor growing seasons.

Closed area. Following a decline in both the mean transect abundance class values and mean number of cells/transect between 1977 and 1998, both of these variables remained about the same in the closed area (Figures 3 and 4 and 16 and 17). The reason for this decline is unclear, but may be the result of differential rainfall between the northern part of the dunes, where the closed area occurs, and the southern part of the dunes, where most of the open area occurs. No data are available to indicate whether less rainfall fell in the northern part of the dunes than in the southern part in either 1977 or 1998. RAWS data collected in 2000-2001 showed that more rainfall fell in the southern part of the dunes than in the northern part during that growing season, so it is possible the same pattern existed in 1998. The lack of an increase between 2001 and 2002, as occurred in the open area, may also be explained by differential rainfall amounts between the north and south.

Open area. In contrast with the closed area, both variables increased between 1977 and 1998 in the open area (Figures 3 and 4 and 16 and 17). The abundance class values then declined in the open area between 1999 and 2001 and then increased in 2002. Although the mean number of cells/transect also declined, this decline did not become apparent until 2000. As with the abundance class values, the decline ended in 2001, and the mean number of occupied cells/transect increased in 2002. The general decline between 1998 and 2001 can possibly be explained by the below-average precipitation in 1999 and 2000. The year 1998 was a good recruitment year for this species, but the low precipitation in 1999 and 2000 may have resulted in significant mortality of existing plants. The precipitation in the 2000-2001 growing season was much better, particularly in the southern part of the dunes, where most of the open area is. This better rainfall, however, did not result in higher values for the two variables in 2001, as would be expected. Instead, the increase occurred between 2001 and 2002, following a growing season that experienced a similar amount of rainfall in the southern part of the dunes as the 2000-2001 growing season, according to the data collected at the Buttercup RAWS station. Environmental conditions favoring HENIT recruitment may involve other factors than growing season total precipitation.

Although the overall response of HENIT between years and the differences between its responses in the closed and open areas are difficult to explain, there appears to be no evidence from these data for an OHV effect. Except for 1977, both the mean transect abundance class totals and the mean number of occupied cells/transect were higher in the open area than in the closed area. Because there is no evidence to support the hypothesis that HENIT is adapted to OHV disturbance, one explanation for this difference is that the southern, higher dunes, which include most of the area open to OHVs, are better habitat for this species than the closed area.

Pholisma sonorae

PHSO abundance does not track growing precipitation to any meaningful extent (r^2 values are 0.12, 0.13, and 0.13, for the entire dunes, the closed area, and the open area, respectively). This may be because its abundance depends upon the health of its host plants, which are all relatively long-lived perennial species. Abundance of this species in the open area was higher in 2002 than in any of the other years. Part of this "increase" appears to be related to the fact that—unlike in previous years--four of the transects in the southern open area of the dunes were walked rather than driven (actually the four transects were both walked and driven, but only the results from the walked transects are included in the analyses presented in this report). Because of the cryptic nature of this plant, Willoughby (2001) postulated that individuals in the open area south of Highway 78 were likely often missed by observers surveying from dune buggies. An examination of the differences between the values obtained by observers who walked and those obtained from observers who drove lends support to this belief. Table 6 shows these differences.

Table 6. PHSO plant counts and abundance class totals from the four transects that were surveyed both by walking and driving in 2002.

	Transect Number			
Number plants tallied	15	20	21	22
From walking transects	18	93	54	57
From driving transects	0	47	42	56
Absolute difference	-18	-46	-12	-1
Percent difference	-100%	-49%	-22%	-2%
Abundance class totals				
From walking transects	6	9	7	9
From driving transects	0	9	6	8
Absolute difference	-6	0	-1	-1
Percent difference	-100%	0%	-14%	-11%

As Table 6 shows, in every case but one (abundance class totals for Transect 20, in which both the walking and driving transects yielded the same values), the walking transects tallied more plants and resulted in higher abundance class totals than the driving transects. This certainly supports the hypothesis that individuals of this species are more likely to be missed by observers in vehicles than those walking. It also probably contributes to the higher values observed in the open area in 2002 compared to the other years. But it does not completely explain these higher values because the abundance class values observed in 2002 are higher than can be accounted for by four out of 24 transects being walked in 2002 but not in the other years. Because this species is cryptic and poses no hazard to vehicle tires, the higher 2002 values may also be the result of the additional protection afforded by the interim vehicle closures. But the fact that the 2001 open area values were not also higher (the closure went into effect in November 2000) may argue against this interpretation. On the other hand, compliance with the closure by OHV users may have improved in 2002 over that in 2001.

Conclusions

The collection and analysis of two more years of monitoring data continue to support the conclusions of Willoughby (2001), who reported on the years 1977, 1998, 1999, and 2000. Healthy populations of ASMAP, HENIT, and PHSO remain in the open area. Though both mean transect abundance class totals and mean number of occupied cells/transect for ASMAP fluctuate dramatically with the amount of growing season precipitation, there is no difference in response between the closed and open areas. For HENIT, there are obvious differences in mean transect abundance class totals and mean number of occupied cells/transect between the closed and open areas, but there is no evidence that this is related to OHV use. For PHSO, there is evidence that the practice of reading transects from a vehicle may have resulted in missing plants in the southern part of the dunes open to OHV use and that, therefore, estimates of mean transect abundance class totals and mean number of occupied cells/transect may be biased low for the open area. Because this species is cryptic and does not pose a hazard to vehicle tires, the increase observed in the open area between 2001 and 2002 may be the result of the interim closures of part of the open area.

The monitoring described in this report ended in 2002. Beginning with a pilot study in 2003, BLM is shifting its monitoring to estimate actual densities and population numbers of the three species, as opposed to the abundance class approach used between 1998-2002.

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Appendix 1

This appendix contains three tables with summary information from the study and eight figures showing monthly precipitation in and near the Algodones Dunes . Table 7 details each year's survey results for each transect and for each of the three species discussed in this report. Number of cells occupied, total abundance class values, and number of plants tallied along each of the 34 transects are given, along with total cells occupied with total cells occupied, total abundance class values, and total number of plants tallied for the entire dunes, the closed area (transects 5-14), the northern open area (transects 1-4), the southern open area (transects 15-34), and all of the open area.

Table 8 shows the number of individual plants of each species tallied while reading the 34 transects in each of the years between 1998 and 2002. No such tallies are available for 1977. These values should not be viewed as or used for population estimates because the tallies were not made in quadrats of a specific size. Observers were instructed to tally plants in an area of approximately 50 m on either side of the center line of each transect (resulting in belt transects about 100 m wide), but no measuring devices were used to ensure this, and visibility along some transects did not extend to 50 m on both sides of the center line (e.g., where high dunes restricted visibility in one direction). Also, the number of observers per transect both within and between years, and tallies would be expected to be higher with an increasing number of observers because fewer plants would be missed. In 2001, in addition to volunteers from the California Native Plant Society and other agencies, volunteers from the American Sand Association (ASA) also made themselves available for some of the monitoring. Thus, 2001 tallies may be higher than they would have been without the additional ASA observers.

Table 9 shows the percent of tallied plants that were seedlings in each of the years for *Astragalus magdalenae* var. *peirsonii* and *Helianthus niveus* ssp. *tephrodes* and the percent of *Pholisma sonorae* inflorescences that were dried at the time of monitoring.

Figures 20-25 show monthly precipitation as recorded by WRCC weather stations in the vicinity of the Algodones Dunes for the growing seasons 1976-1977, 1997-1998, 1998-1999, 1999-2000, 2000-2001, and 2001-2002. Figures 26-27 show monthly precipitation as recorded at the two RAWS stations for the growing seasons 2000-2001 and 2001-2002 (because the RAWS stations were not established until November 16, 2000, Figure 26 shows monthly precipitation only for the period between November 16, 2000, and June 30, 2001).

Table 7. Transect details showing number of cells occupied, total abundance class values, and number of plants tallied along each of the 34 transects for each species in 1977, 1998, 1999, 2000, 2001, and 2002. Also given are total cells occupied, total abundance class values, and total number of plants tallied for the entire dunes, the closed area (transects 5-14), the northern open area (transects 1-4), the southern open area (transects 15-34), and all of the open area. Abbreviations are: ASMAP = *Astragalus magdalenae* var. *peirsonii*; HENIT = *Helianthus niveus* ssp. *tephrodes*; PHSO = *Pholisma sonorae*.

ASMAP

	1977			1998			1999			2000			2001			2002		
Transect Number	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied
1	0	0	N/A	1	1	11	1	1	9	0	0	0	2	3	27	0	0	0
2	1	1	N/A	2	3	29	2	3	16	1	1	4	1	2	25	0	0	0
3	0	0	N/A	2	4	108	2	2	10	0	0	0	1	1	8	1	1	1
4	1	1	N/A	2	4	418	2	2	11	1	1	1	2	3	27	3	3	9
5	3	5	N/A	3	4	38	2	2	2	1	1	2	2	4	327	2	2	7
6	0	0	N/A	2	4	83	1	2	11	1	1	1	2	4	211	1	1	4
7	3	5	N/A	3	6	49	1	1	4	0	0	0	3	7	286	2	3	53
8	3	6	N/A	2	4	33	1	1	5	1	1	1	2	5	267	2	3	17
9	3	6	N/A	3	4	22	2	2	5	0	0	0	2	4	111	2	4	51
10	3	8	N/A	3	5	313	1	1	1	1	1	1	3	6	184	2	4	50
11	0	0	N/A	4	6	60	2	2	11	2	2	2	4	9	679	3	6	174
12	4	6	N/A	3	4	10	3	3	10	0	0	0	4	8	459	2	3	95
13	6	11	N/A	3	5	41	3	4	21	3	3	6	3	3	5	3	3	6
14	3	6	N/A	5	7	45	5	6	60	3	3	7	0	0	0	1	1	5
15	6	8	N/A	5	8	88	3	3	4	0	0	0	0	0	0	1	1	3
16	6	9	N/A	6	12	222	5	5	14	0	0	0	0	0	0	0	0	0
17	9	17	N/A	9	21	857	3	3	10	8	8	20	4	8	277	4	7	158
18	8	15	N/A	5	10	171	3	5	59	3	3	4	4	10	568	3	4	24
19	4	7	N/A	7	13	191	4	4	20	0	0	0	4	5	41	0	0	0
20	3	5	N/A	5	9	83	1	1	3	0	0	0	2	4	129	4	4	14
21	3	3	N/A	5	7	79	2	3	12	0	0	0	1	1	1	0	0	0
22	2	3	N/A	4	6	98	2	4	80	0	0	0	2	2	8	0	0	0

ASMAP

	1977			1998			1999			2000			2001			2002		
Transect Number	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied
23	2	3	N/A	4	7	221	3	4	44	0	0	0	1	2	23	1	1	1
24	0	0	N/A	6	9	103	2	4	58	1	1	1	3	5	206	2	4	40
25	0	0	N/A	7	10	69	2	3	21	0	0	0	1	2	46	1	2	13
26	1	1	N/A	3	6	131	3	5	31	2	2	7	2	5	225	4	7	128
27	0	0	N/A	4	10	672	2	3	26	0	0	0	4	9	340	3	5	102
28	1	1	N/A	4	8	203	2	3	25	1	1	2	5	9	223	4	10	351
29	2	2	N/A	4	8	272	3	4	20	1	1	2	4	7	244	5	9	321
30	4	5	N/A	0	0	0	2	5	197	2	2	9	2	5	159	5	10	235
31	1	2	N/A	2	2	8	1	2	39	1	2	11	4	9	474	3	7	306
32	0	0	N/A	3	7	335	3	5	103	2	2	5	3	6	221	3	6	125
33	4	4	N/A	1	1	1	0	0	0	0	0	0	5	8	77	0	0	0
34	4	7	N/A	0	0	0	0	0	0	0	0	0	2	3	52	1	1	4
Total All	90	147	N/A	122	215	5,064	74	98	942	35	36	86	84	159	5,930	68	112	2,297
Total Closed (5-14)	28	53	N/A	31	49	694	21	24	130	12	12	20	25	50	2,529	20	30	462
Total No. Open (1-4)	2	2	N/A	7	12	566	7	8	46	2	2	5	6	9	87	4	4	10
Total So. Open (15-34)	60	92	N/A	84	154	3,804	46	66	766	21	22	61	53	100	3,314	44	78	1,825
Total All Open	62	94	N/A	91	166	4,370	53	74	812	23	24	66	59	109	3,401	48	82	1,835

HENIT

	1977			1998			1999			2000			2001			2002		
Transect Number	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied
1	0	0	N/A	2	3	33	1	2	12	0	0	0	1	1	1	1	1	3
2	3	8	N/A	2	3	24	2	3	35	2	3	20	1	1	4	2	2	14
3	0	0	N/A	2	3	78	2	2	2	0	0	0	0	0	0	0	0	0
4	1	1	N/A	2	4	14	2	4	97	2	5	122	2	5	257	2	4	100
5	5	10	N/A	1	1	4	2	2	7	2	2	11	1	2	123	1	2	35
6	5	8	N/A	2	3	61	1	2	17	3	3	7	1	2	43	2	4	83
7	0	0	N/A	2	2	6	2	2	8	3	3	8	2	3	52	2	3	41
8	5	10	N/A	1	2	8	1	1	1	1	1	2	2	2	3	1	1	2
9	3	7	N/A	3	6	243	1	2	35	1	2	21	1	3	597	3	5	220
10	6	13	N/A	2	5	289	3	5	125	2	4	98	4	8	430	3	6	266
11	0	0	N/A	7	14	868	3	7	169	5	9	223	5	12	956	4	9	629
12	5	8	N/A	2	6	34	4	8	201	4	9	259	4	10	1110	4	9	355
13	7	14	N/A	2	3	37	4	7	141	5	9	108	4	6	56	5	8	139
14	7	12	N/A	3	5	8	4	9	293	5	8	161	2	5	682	3	5	106
15	6	10	N/A	10	18	26	8	12	127	10	16	220	8	9	88	11	15	130
16	7	11	N/A	7	14	42	10	13	108	9	15	174	6	8	42	8	13	237
17	10	13	N/A	10	22	94	10	18	354	9	10	42	9	15	201	9	14	175
18	11	22	N/A	10	22	188	13	25	469	11	14	90	9	16	243	9	14	148
19	2	3	N/A	10	22	472	11	19	360	8	13	138	8	14	643	12	15	154
20	4	5	N/A	8	16	373	10	20	331	9	15	293	9	14	210	9	14	296
21	5	6	N/A	8	23	388	7	15	391	7	13	343	8	12	131	9	14	167
22	2	3	N/A	8	20	260	8	17	393	5	8	133	7	10	97	9	15	285

HENIT

	1977			1998			1999			2000			2001			2002		
Transect Number	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied
23	2	3	N/A	9	23	253	8	17	343	7	12	220	6	9	94	3	7	194
24	1	2	N/A	6	16	138	6	10	80	7	13	173	7	8	47	6	9	91
25	0	0	N/A	8	23	130	7	14	278	7	12	98	5	8	67	8	12	72
26	2	4	N/A	7	20	221	6	11	215	8	17	453	2	4	71	9	15	251
27	0	0	N/A	8	25	484	9	19	458	9	15	215	5	10	340	9	21	872
28	4	4	N/A	5	14	281	10	16	187	7	14	200	6	11	241	10	20	829
29	5	5	N/A	4	7	52	7	13	239	8	14	186	3	3	10	8	13	223
30	5	9	N/A	3	8	124	8	17	693	8	15	180	3	3	11	9	17	592
31	3	4	N/A	6	16	234	6	14	666	6	13	285	5	6	41	9	17	273
32	3	4	N/A	4	9	191	8	15	553	9	14	151	6	6	31	9	18	645
33	5	6	N/A	2	6	139	3	5	54	4	6	32	2	3	65	5	7	109
34	5	7	N/A	2	4	54	7	11	103	8	9	68	10	18	389	10	19	482
Total All	129	212	N/A	168	388	5,851	194	357	7,545	191	316	4,734	154	247	7,376	204	348	8,218
Total Closed (5-14)	43	82	N/A	25	47	1,558	25	45	997	31	50	898	26	53	4,052	28	52	1,876
Total No. Open (1-4)	4	9	N/A	8	13	149	7	11	146	4	8	142	4	7	262	5	7	117
Total So. Open (15-34)	82	121	N/A	135	328	4,144	162	301	6,402	156	258	3,694	124	187	3,062	171	289	6,225
Total All Open	86	130	N/A	143	341	4,293	169	312	6,548	160	266	3,836	128	194	3,324	176	296	6,342

PHSO

	1977			1998			1999			2000			2001			2002		
Transect Number	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied
1	0	0	N/A	2	3	31	1	2	15	2	2	5	0	0	0	1	2	8
2	0	0	N/A	3	3	7	1	1	4	3	5	31	0	0	0	0	0	0
3	0	0	N/A	4	9	91	3	6	89	3	8	114	3	10	351	3	7	91
4	1	1	N/A	3	4	14	2	3	13	5	13	213	5	15	968	4	13	691
5	1	1	N/A	3	5	30	1	1	1	2	8	242	2	6	131	1	3	35
6	0	0	N/A	4	5	18	3	3	8	4	6	32	1	4	119	2	5	53
7	1	2	N/A	5	10	82	0	0	0	4	10	188	4	7	59	4	6	33
8	0	0	N/A	4	6	20	3	3	6	3	4	15	3	7	49	5	7	58
9	0	0	N/A	2	4	38	3	3	5	2	2	2	4	7	39	5	15	171
10	1	1	N/A	2	2	7	1	1	4	2	6	67	5	11	331	3	6	40
11	0	0	N/A	5	9	33	1	1	7	4	9	82	5	16	495	3	7	81
12	0	0	N/A	0	0	0	1	1	5	3	7	109	5	13	1050	4	5	15
13	3	3	N/A	4	6	31	1	1	1	5	18	396	4	4	12	4	6	23
14	0	0	N/A	4	9	53	3	5	20	5	11	72	2	2	6	5	7	26
15	0	0	N/A	0	0	0	1	2	7	0	0	0	0	0	0	4	6	18
16	1	1	N/A	1	1	4	1	1	2	0	0	0	1	2	8	2	3	18
17	1	2	N/A	0	0	0	0	0	0	0	0	0	0	0	0	3	5	34
18	3	6	N/A	3	4	18	0	0	0	0	0	0	0	0	0	5	9	58
19	1	1	N/A	1	1	5	1	1	1	0	0	0	0	0	0	6	9	53
20	3	3	N/A	0	0	0	0	0	0	0	0	0	0	0	0	7	9	46
21	3	4	N/A	0	0	0	2	2	3	0	0	0	0	0	0	4	7	54
22	1	4	N/A	0	0	0	2	2	2	0	0	0	0	0	0	5	9	57

PHSO

	1977			1998			1999			2000			2001			2002		
Transect Number	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied	Number Cells Occupied	Sum of Abun. Class Values	Number Plants Tallied
23	1	2	N/A	0	0	0	1	1	5	0	0	0	0	0	0	3	7	47
24	2	2	N/A	0	0	0	1	1	2	0	0	0	5	9	43	6	11	76
25	0	0	N/A	0	0	0	1	1	2	0	0	0	2	6	52	3	6	48
26	2	2	N/A	0	0	0	1	2	11	1	1	1	0	0	0	4	11	164
27	0	0	N/A	0	0	0	1	1	1	0	0	0	0	0	0	3	9	182
28	0	0	N/A	0	0	0	1	1	1	2	2	6	0	0	0	2	7	104
29	2	2	N/A	0	0	0	1	1	1	1	1	1	1	1	4	3	8	112
30	0	0	N/A	1	1	1	7	13	83	0	0	0	0	0	0	3	8	155
31	0	0	N/A	2	2	2	2	3	23	0	0	0	1	2	9	4	12	469
32	4	6	N/A	0	0	0	2	6	43	0	0	0	0	0	0	3	10	297
33	4	4	N/A	1	1	1	3	4	20	0	0	0	0	0	0	0	0	0
34	4	10	N/A	0	0	0	0	0	0	0	0	0	2	3	14	0	0	0
Total All	39	57	N/A	54	85	486	52	73	385	51	113	1,576	55	125	3,740	114	235	3,317
Total Closed (5-14)	6	7	N/A	33	56	312	17	19	57	34	81	1,205	35	77	2,291	36	67	535
Total No. Open (1-4)	1	1	N/A	12	19	143	7	12	121	13	28	363	8	25	1,319	8	22	790
Total So. Open (15-34)	32	49	N/A	9	10	31	28	42	207	4	4	8	12	23	130	70	146	1,992
Total All Open	33	50	N/A	21	29	174	35	54	328	17	32	371	20	48	1,449	78	168	2,782

Table 8. Total number of seedlings and adult plants tallied along transects in 1998, 1999, 2000, 2001, and 2002 for each species in the closed area, open area, and the entire dunes. Abundance class values for cells along transects were determined using the total of seedlings and adult plants, also shown below. Abbreviations are: ASMAP = *Astragalus magdalenae* var. *peirsonii*; HENIT = *Helianthus niveus* ssp. *tephrodes*; PHSO = *Pholisma sonorae*. There are 34 total transects, 10 in the closed area and 24 in the open area. For PHSO, numbers are for dried flower heads (listed under the heading "seedlings") and living flower heads (listed under the heading "adults").

		Closed Area			Open Area			Entire Dunes		
Species	Year	Seed-lings	Adults	Total	Seed-lings	Adults	Total	Seed-lings	Adults	Total
ASMAP	1998	29	665	694	22	4,348	4,370	51	5,013	5,064
	1999	0	130	130	0	812	812	0	942	942
	2000	0	20	20	0	66	66	0	86	86
	2001	275	2,254	2,529	469	2,932	3,401	744	5,186	5,930
	2002	4	458	462	150	1,685	1,835	154	2,143	2,297
HENIT	1998	758	800	1,558	90	4,203	4,293	848	5,003	5,851
	1999	1	996	997	289	6,259	6,548	290	7,255	7,545
	2000	2	896	898	7	3,829	3,836	9	4,725	4,734
	2001	2,121	1,931	4,052	851	2,473	3,324	2,972	4,404	7,376
	2002	4	1,872	1,876	1,020	5,322	6,342	1,024	7,194	8,218
PHSO	1998	144	168	312	27	147	174	171	315	486
	1999	52	5	57	106	222	328	158	227	385
	2000	48	1,157	1,205	26	345	371	74	1,502	1,576
	2001	71	2,220	2,291	96	1,353	1,449	167	3,573	3,740
	2002	217	318	535	403	2,379	2,782	620	2,657	3,317

Table 9. Percent seedling plants by year for each species (for PHSO the numbers are the percent of dried inflorescences).

		Percent Seedling Plants		
Species	Year	Closed Area	Open Area	Entire Dunes
ASMAP	1998	4.2	0.5	1.0
	1999	0.0	0.0	0.0
	2000	0.0	0.0	0.0
	2001	10.9	13.8	12.5
	2002	0.9	8.2	6.7
HENIT	1998	48.7	2.1	14.5
	1999	0.1	4.4	3.8
	2000	0.2	0.2	0.2
	2001	52.3	25.6	40.3
	2002	0.2	16.1	12.5
PHSO	1998	46.2	15.5	35.2
	1999	91.2	32.3	41.0
	2000	4.0	7.0	4.7
	2001	3.1	6.6	4.5
	2002	40.6	14.5	18.7

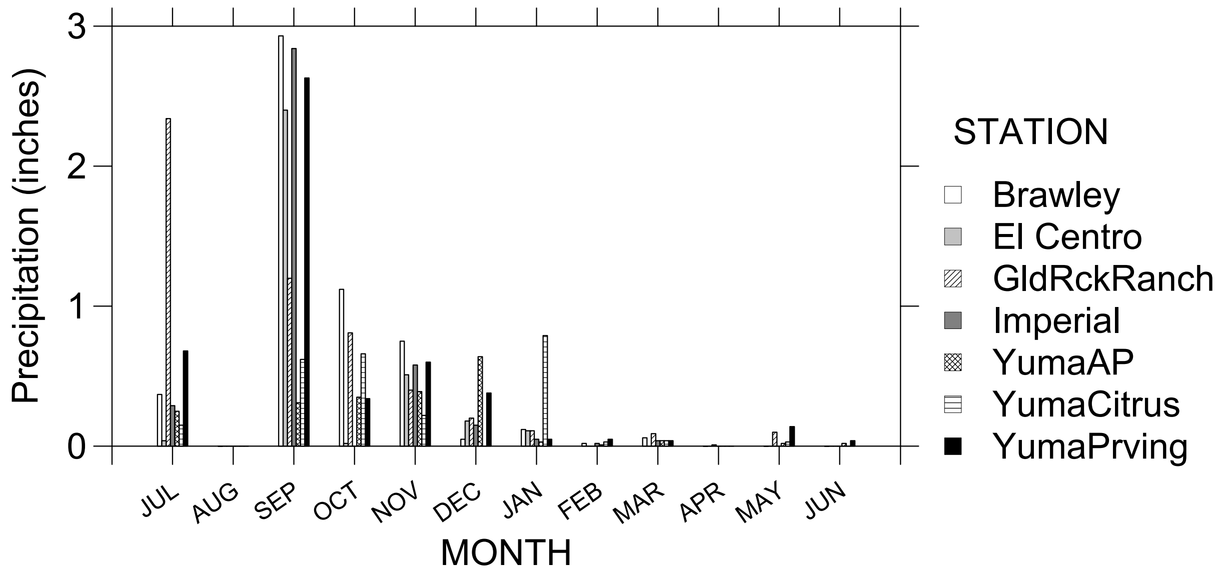


Figure 20. Monthly precipitation for the 1976-1977 growing season as recorded by WRCC weather stations in the vicinity of the Algodones Dunes.

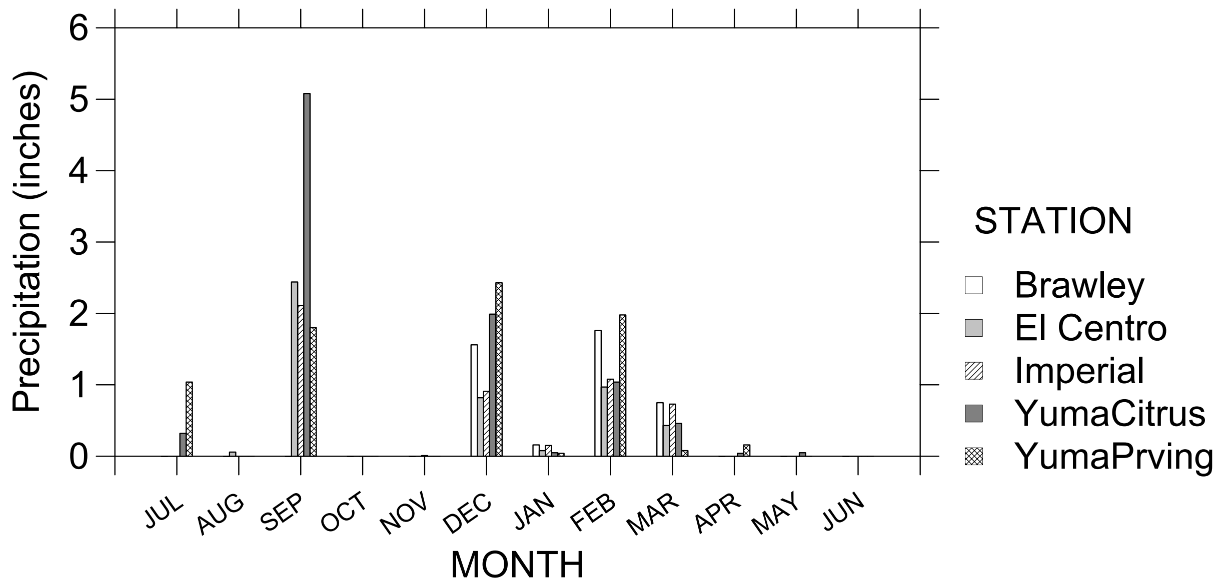


Figure 21. Monthly precipitation for the 1997-1998 growing season as recorded by WRCC weather stations in the vicinity of the Algodones Dunes.

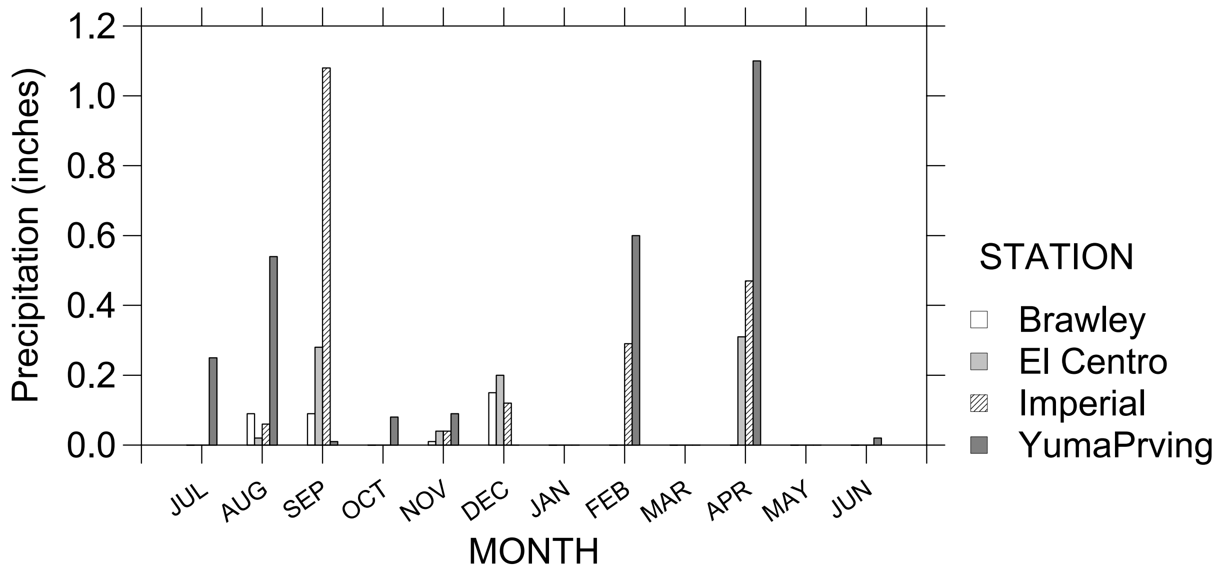


Figure 22. Monthly precipitation for the 1998-1999 growing season as recorded by WRCC weather stations in the vicinity of the Algodones Dunes.

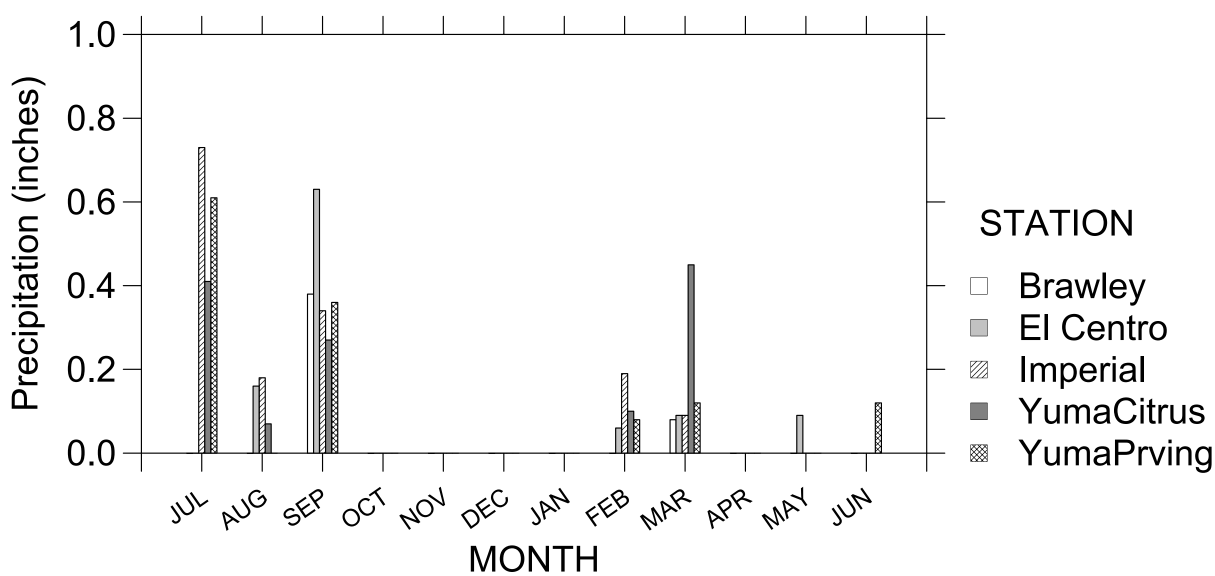


Figure 23. Monthly precipitation for the 1999-2000 growing season as recorded by WRCC weather stations in the vicinity of the Algodones Dunes.

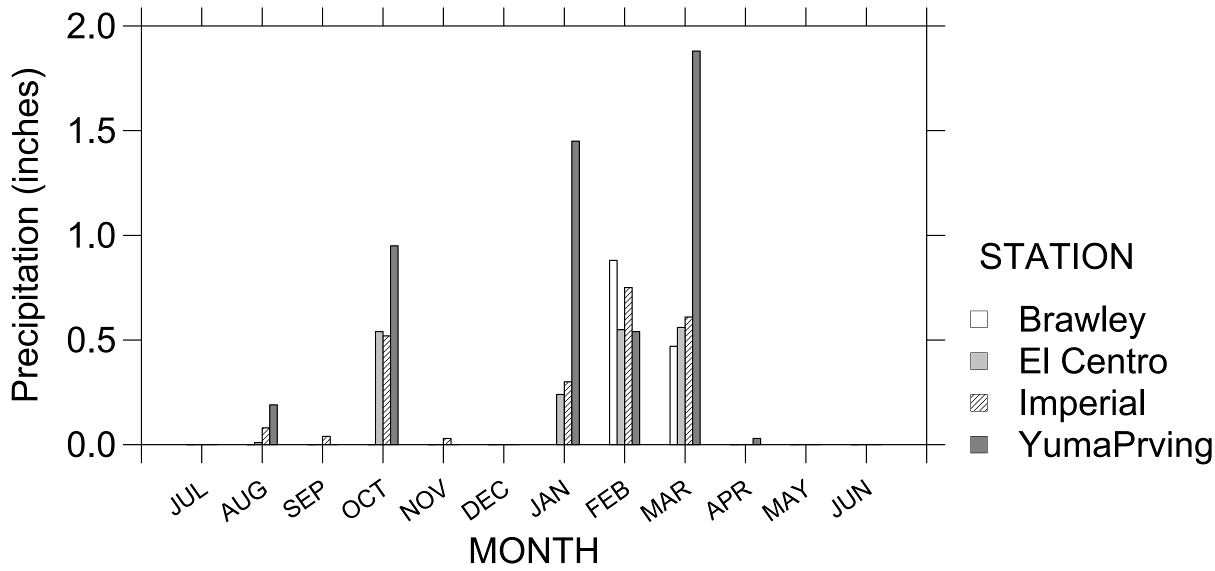


Figure 24. Monthly precipitation for the 2000-2001 growing season as recorded by WRCC weather stations in the vicinity of the Algodones Dunes.

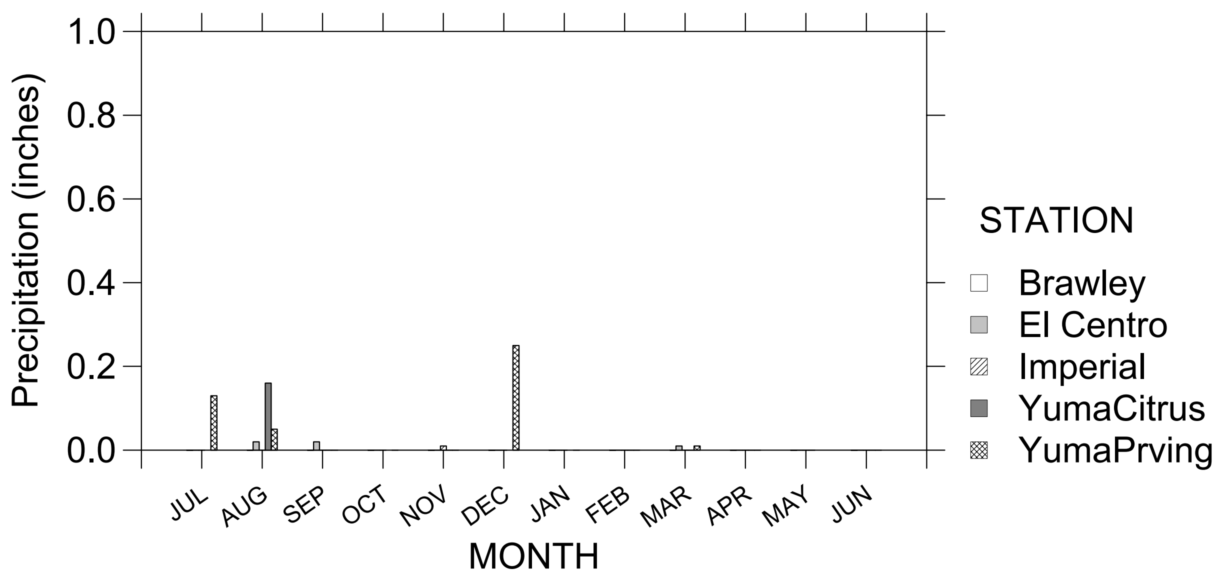


Figure 25. Monthly precipitation for the 2001-2002 growing season as recorded by WRCC weather stations in the vicinity of the Algodones Dunes.

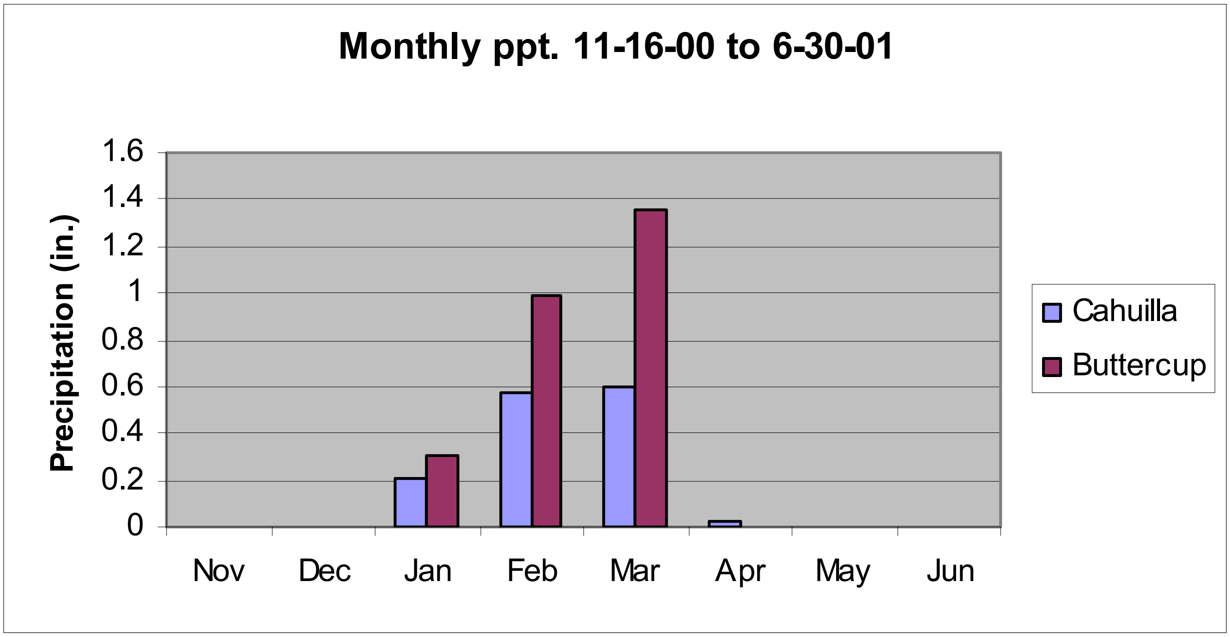


Figure 26. Monthly precipitation for the 2000-2001 growing season as recorded by the two Remote Area Weather Stations (RAWS) in the Algodones Dunes. Because the stations were established on November 16, 2000, only data recorded between November 16, 2000, and June 30, 2001 are shown.

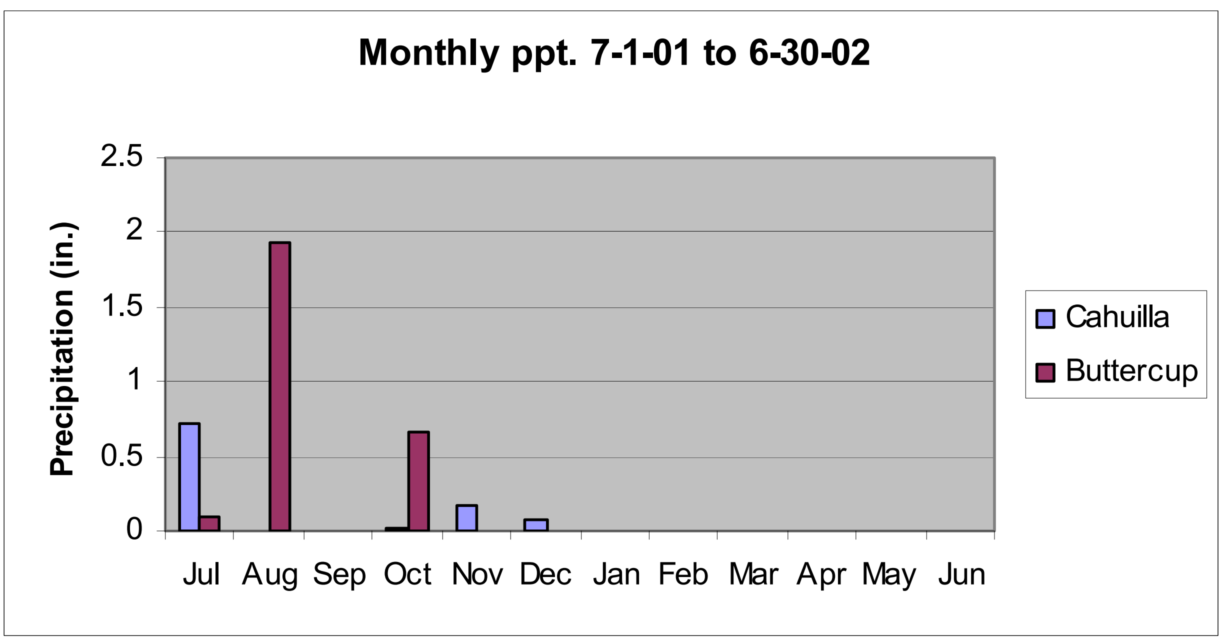
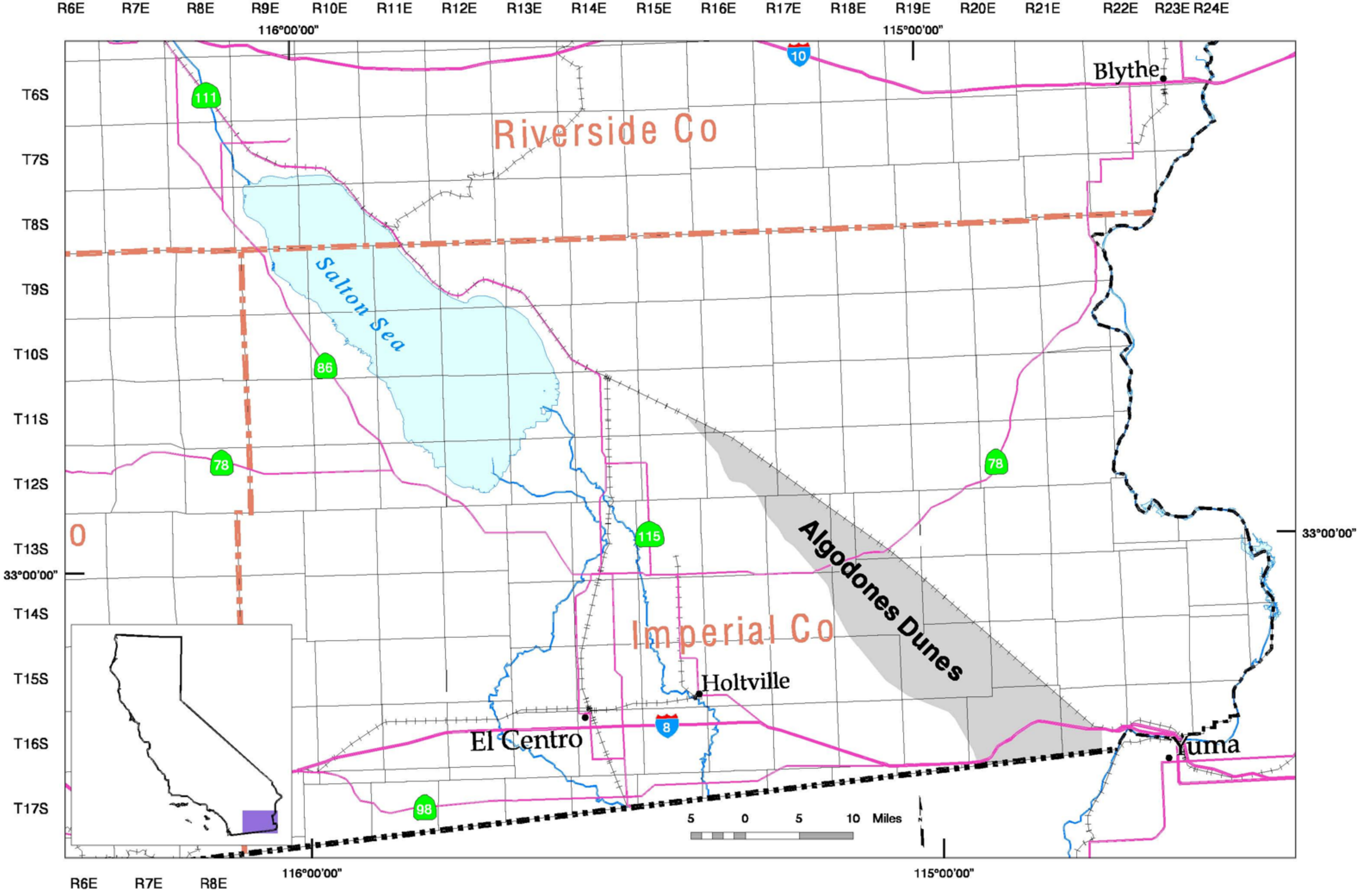
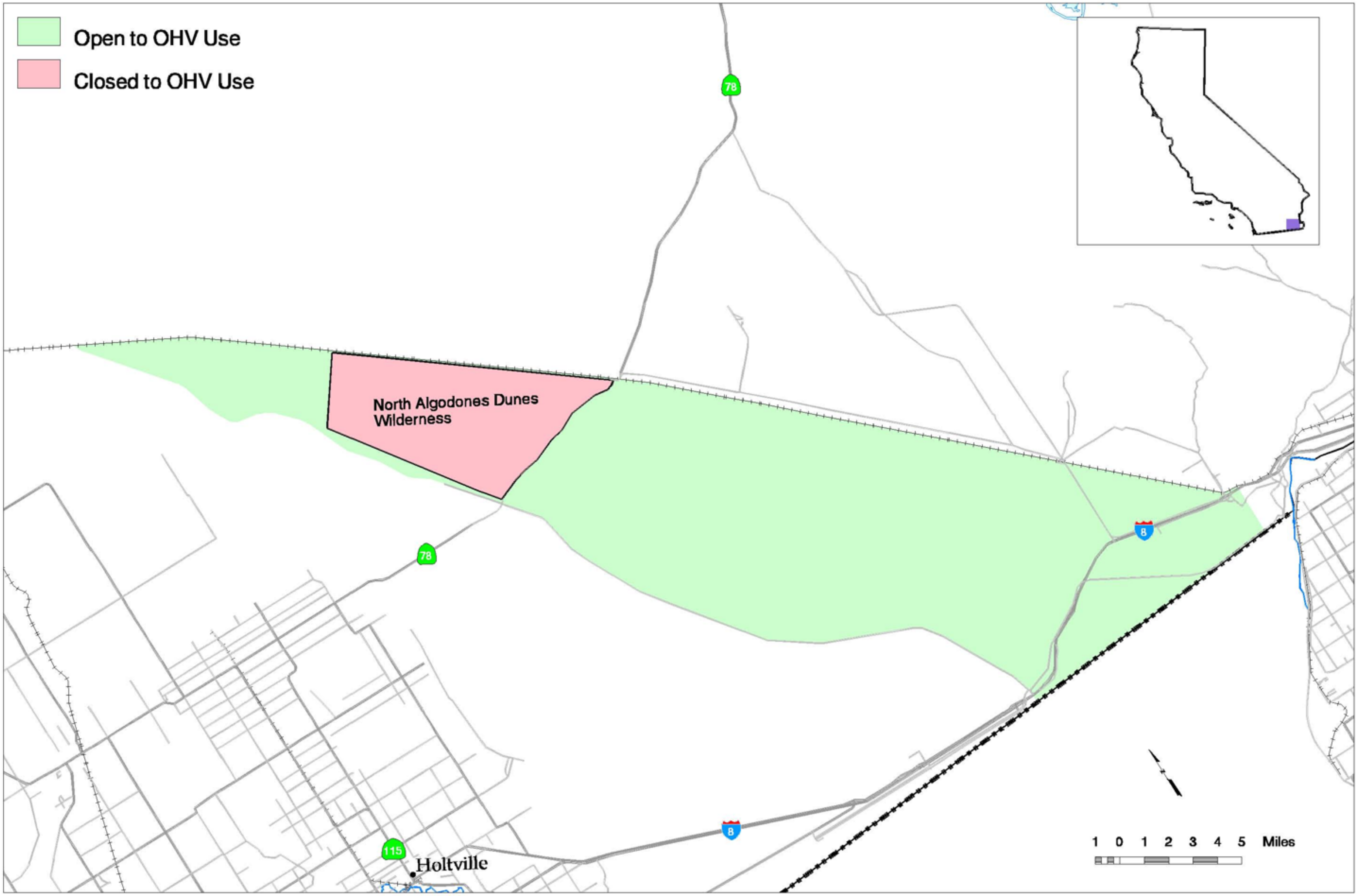


Figure 27. Monthly precipitation for the 2001-2002 growing season as recorded by the two Remote Area Weather Stations (RAWS) in the Algodones Dunes.

Map 1: Algodones Dunes and Vicinity

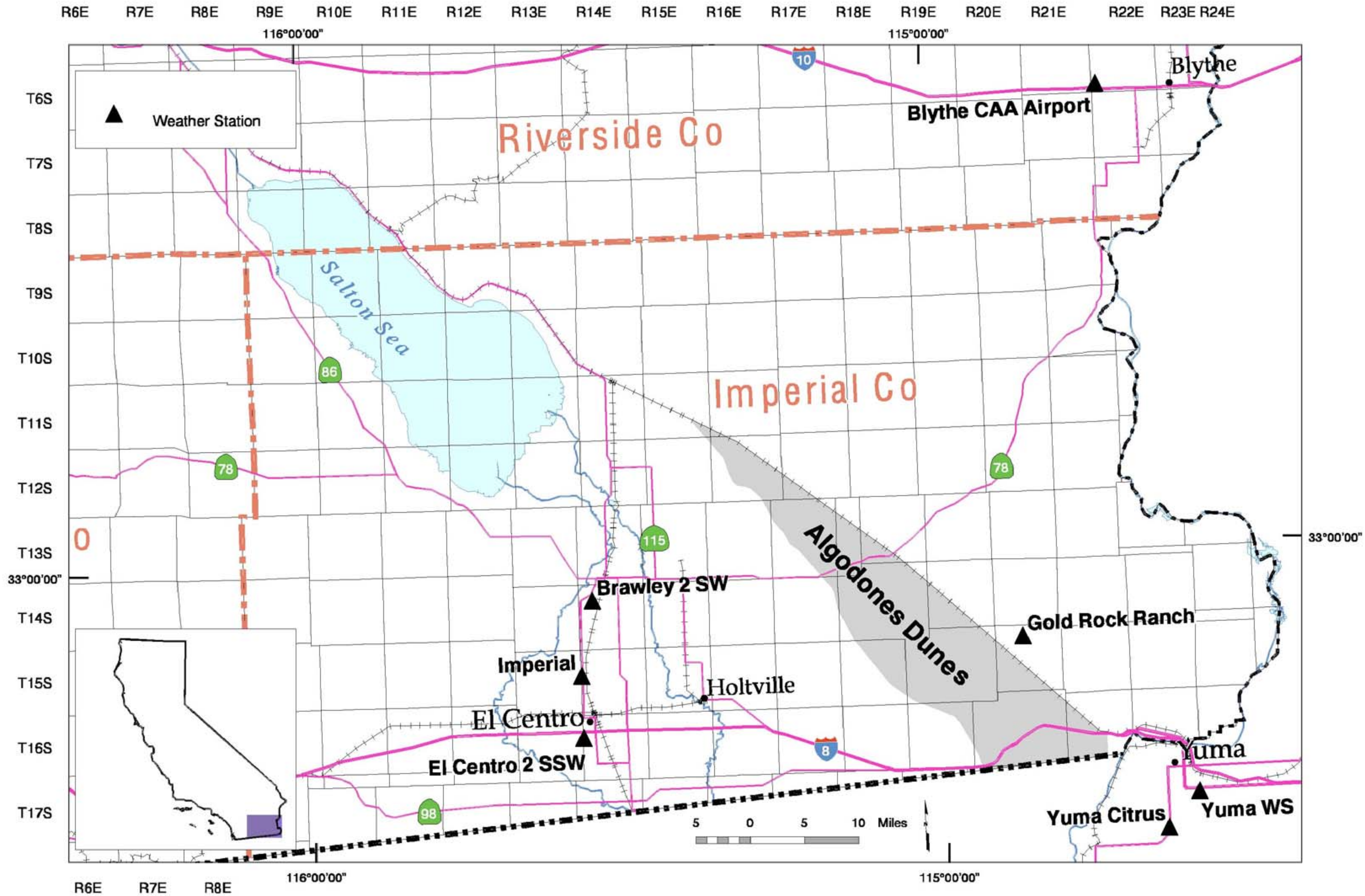


Map 2: Algodones Dunes OHV Use

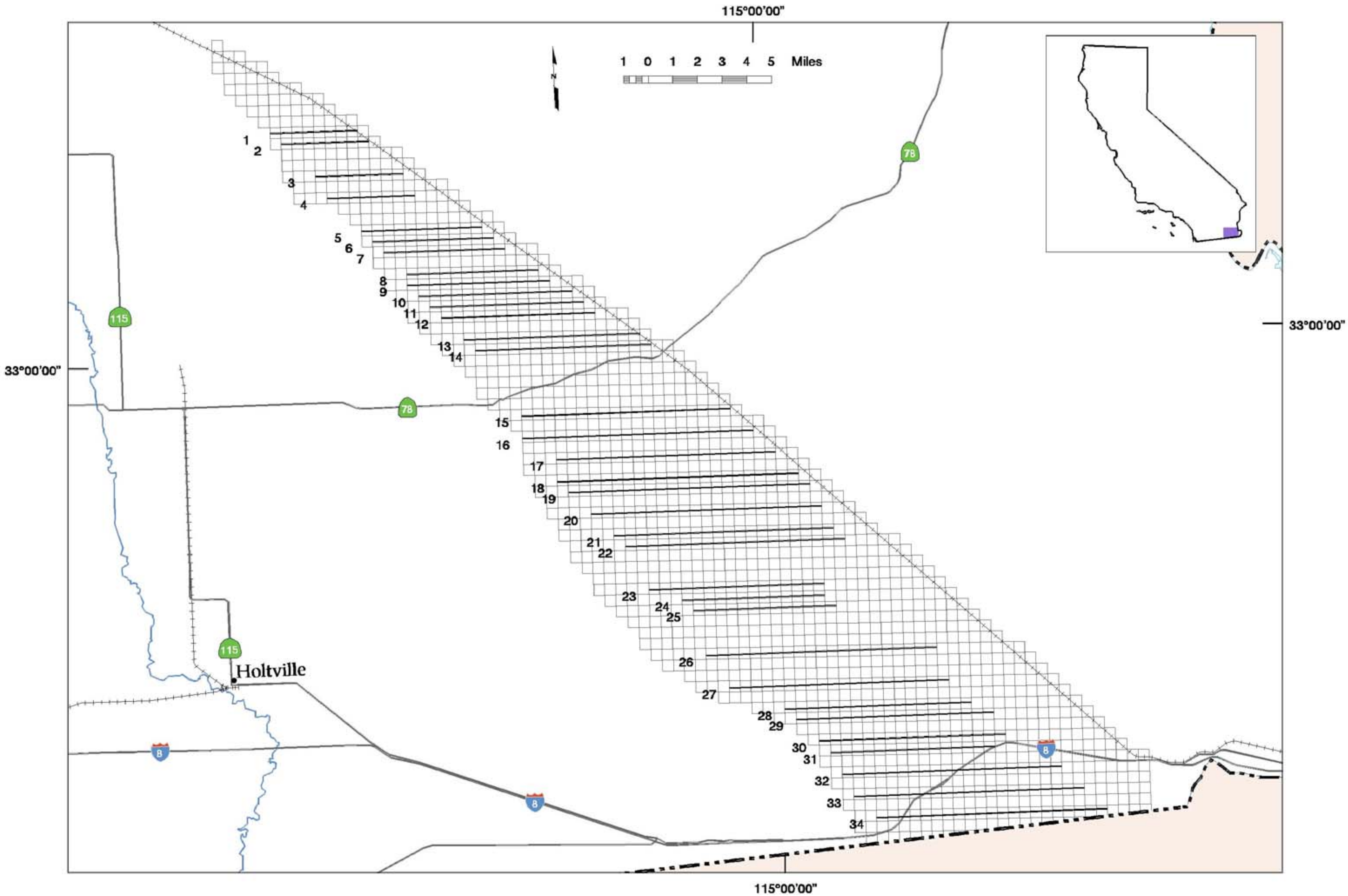


Map 3: Sampling Grid Used in WESTEC's 1977 Algodones Dunes Study

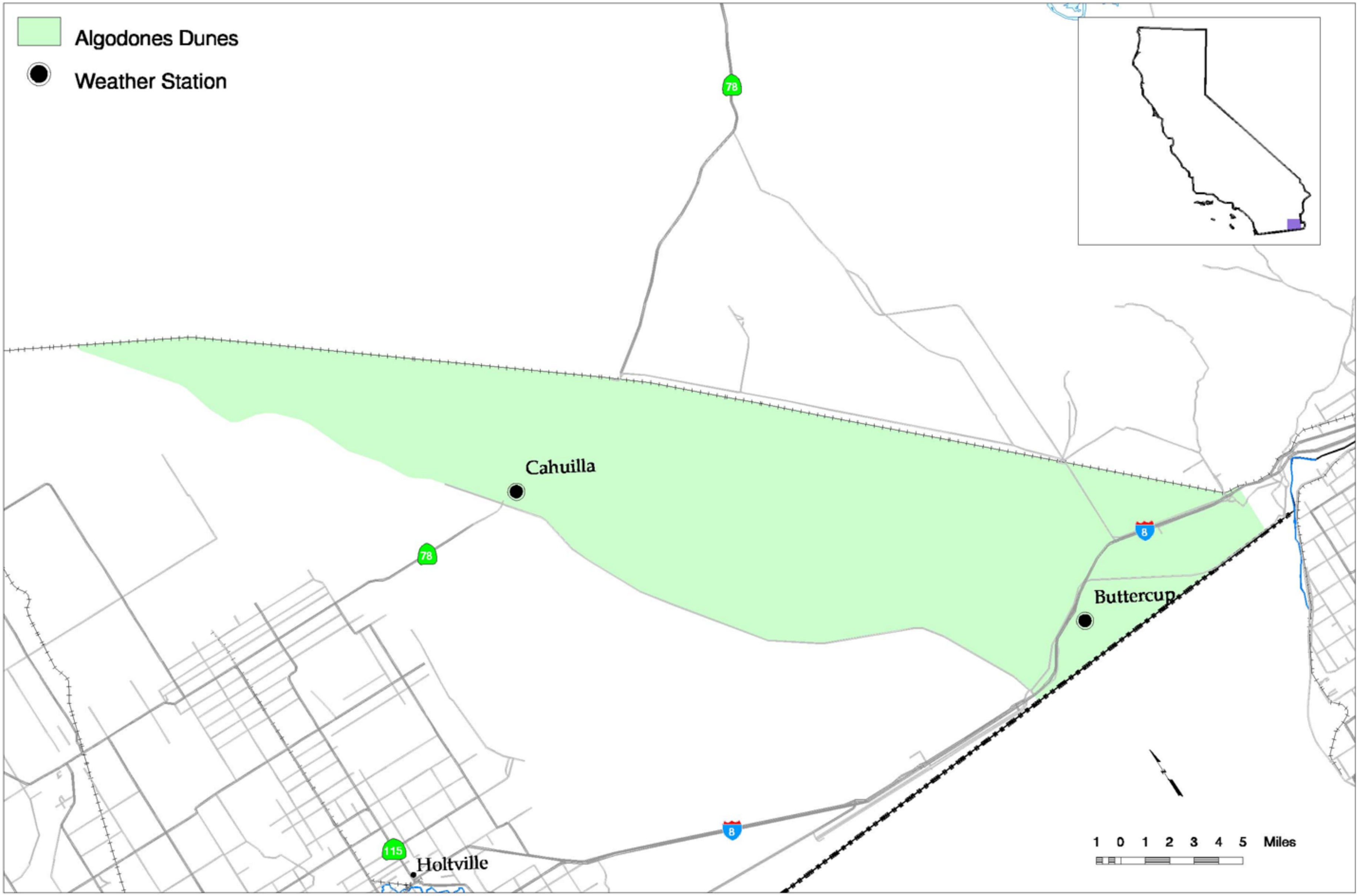
Map 4: Weather Stations Near the Algodones Dunes



Map 5: Transect Locations for BLM's 1998 Algodones Dunes Study



Map 6: Remote Area Weather Stations (RAWS) in the Algodones Dunes



Map 7: Interim Closures Instituted in November 2000